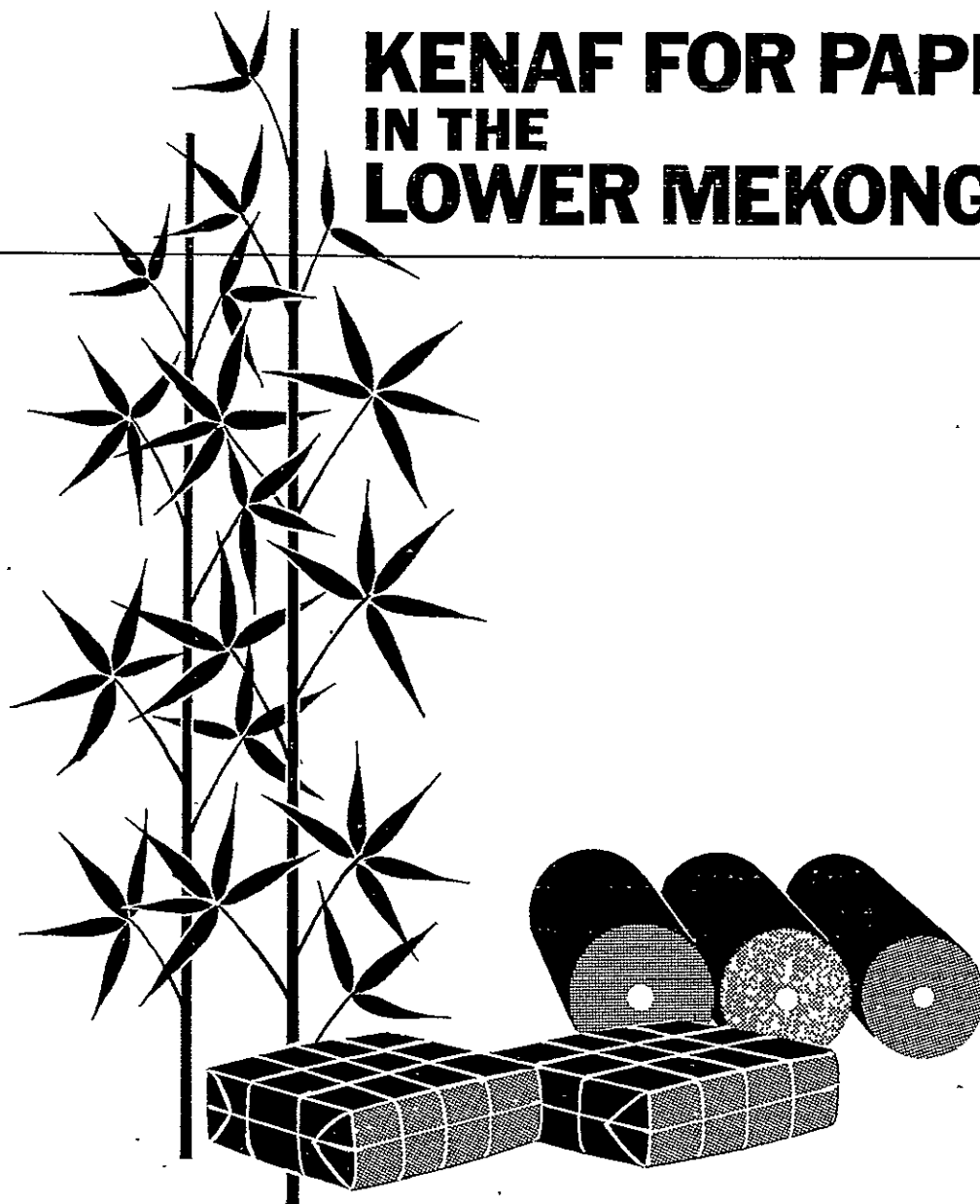


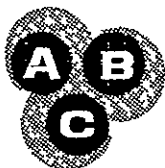
KENAF FOR PAPER PULP IN THE LOWER MEKONG BASIN



A. Pre-Feasibility Study Prepared for
THE COMMITTEE FOR COORDINATION OF INVESTIGATIONS
OF THE LOWER MEKONG BASIN

By

JOSEPH E. ATCHISON CONSULTANTS, INC.
In Association with
AGRI-BUSINESS CONSULTANTS



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Bangkok, Thailand

by

Joseph E. Atchison Consultants, Inc.
30 East 42nd Street
New York, N.Y. 10017, U.S.A.

Agri-Business Consultants
P.O. Box 1104, Gd. Central Stn.
New York, N.Y. 10017, U.S.A.

(T. T. COLLINS, JR, AND
R. E. L. WHELESS)

(E. J. SHOLTON)

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KENAF FOR PAPER PULP

in the

LOWER MEKONG BASIN

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LIST OF ABBREVIATIONS

AD	Air Dry (10% Moisture Content)
ADMT	Air Dry Metric Ton
ASRCT	Applied Scientific Research Corporation of Thailand
฿	Baht
CdE	A Bleaching Sequence of Chlorination & Chlorine Dioxide - Alkaline Extraction
CED	A Bleaching Sequence of Chlorination - Alkaline Extraction - Chlorine Dioxide
CEDED	A Bleaching Sequence of Chlorination - Alkaline Extraction - Chlorine Dioxide - Alkaline Extraction - Chlorine Dioxide
CdEHD	A Bleaching Sequence of Chlorination & Chlorine Dioxide - Alkaline Extraction - Hypochlorite - Chlorine Dioxide
CEH	A Bleaching Sequence of Chlorination - Alkaline Extraction - Hypochlorite
CEHD	A Bleaching Sequence of Chlorination - Alkaline Extraction - Hypochlorite - Chlorine Dioxide
CEHEH	A Bleaching Sequence of Chlorination - Alkaline Extraction - Hypochlorite - Alkaline Extraction - Hypochlorite
CEHH	A Bleaching Sequence of Chlorination - Alkaline Extraction - Hypochlorite - Hypochlorite
CSF	Canadian Standard Freeness Tester
CSIRO	Commonwealth Scientific and Industrial Research Organization
FAO	Food & Agriculture Organization of the United Nations
FD	Field Dry (12½% Moisture Content)

FDMT	Field Dry Metric Ton
GE	General Electric Brightness Tester (TAPPI Standard T 217 m 48)
<u>H. cannabinus</u>	<u>Hibiscus cannabinus L.</u> (Western Hemisphere Kenaf)
<u>H. sabdariffa</u>	<u>Hibiscus sabdariffa</u> var. <u>altissima</u> (South Asian Kenaf)
M-C (Process)	Mechano-Chemical (Process)
NRRL	Northern Regional Research Laboratory of the U.S. Department of Agriculture
OD	Oven Dry
ODMT	Oven Dry Metric Ton
PFI	(Papir Industriens Forskningsinstitut) Mill - A Laboratory Refiner for Pulp
\$	United States Dollar
S.-R.	Schopper-Riegler
TAPPI	Technical Association of the Pulp and Paper Industry
tpd.	Tons per Day
tpy.	Tons per Year
USDA	United States Department of Agriculture

UNITS OF MEASURE:

mm.	Millimeter
cm.	Centimeter
cc.	Cubic Centimeter
m.	Meter

km.	Kilometer
in.	Inch
ft.	Foot
sq.m.	Square Meter
sq.ft.	Square Foot
ha.	Hectare (1 ha. = 2.5 Acres = 6.25 Rai Approx.)
cu.m.	Cubic Meter
cu.ft.	Cubic Foot
g.	Gram
kg.	Kilogram
ml.	Milliliter
°C	Degree Centigrade
°F	Degree Fahrenheit

- Objectives and Scope of the Kenaf for Paper Pulp
Pre-Feasibility Study

There are five major objectives of this Pre-Feasibility Study of the techno-economic aspects for manufacturing paper pulp from kenaf. The first is to make a practical and realistic appraisal of the extensive technical work on kenaf fiber preparation and pulping that has been carried on in all parts of the world. The development work on the pulping of this particular fibrous raw material also has to be related to the conventional manufacturing processes currently used to produce pulp from all types of fibrous raw materials. Particular consideration has to be given to employing processes which are already in widespread use by mills pulping other nonwood plant fibers.

The scope of a Pre-Feasibility Study does not allow a detailed technical investigation and financial analysis of all the possibilities for manufacturing the entire spectrum of grades of pulps and papers which could be made from kenaf. Therefore, the Consultants have had to prejudge, based on their experience and the overall picture the situation presents, which of the several technical alternatives would be the most logical to study and would have the best potential for planning a model mill that would be economically viable and would fulfill the needs of the Mekong Basin countries for the foreseeable future.

The agro-economic portion of this Study will summarize the history of kenaf and allied fibers in the riparian countries, examine the actual and potential kenaf production areas, and discuss the production, availability, procurement, and costs of the whole stalk and bast ribbon of kenaf for pulping. In parallel with that, another short range objective will be to develop the technical parameters of a model project to manufacture unbleached and bleached kenaf chemical pulps of types that could replace the hardwood and softwood chemical pulps that are presently imported by the existing paper industry in the Mekong Basin countries.

Manufacturing a range of pulps is made possible by the fact that kenaf bast ribbon chemical pulp has strength properties for paper-making comparable to world market sulfate pulps from major softwood species and whole stalk pulp is quite similar to hardwood sulfate and softwood sulfite pulps. This maximum versatility of pulp product types from a single fibrous raw material is one of the most favorable attributes possessed by kenaf as compared to other fibrous raw materials used for papermaking.

A third and long range objective of this Study is to show the need and potential for eventually manufacturing several grades of paper in the project mill with kenaf as the major fibrous raw material. This would be done when the market could absorb the paper grades without an abrupt and disruptive shutdown of existing small paper mills. Proper planning of the model for the initial project takes into consideration this very important requirement for eventual and gradual transition into paper manufacture. This objective can be met in later years at a minimum additional investment by the initial choice of a pulp machine of the fourdrinier, can-dryer type that can subsequently be modified to run several major grades of paper as well as market pulp for the other mills in the Mekong riparian countries.

A fourth major objective of this Study is to estimate the investment required, the operating cost, and the economic viability of a mill initially designed to meet the prior objectives. This requires consideration of potential sites with adequate fibrous raw material supplies of both kenaf whole stalk and bast ribbon and recommendation of the most advantageous locations with existing infrastructure for a pulp mill to serve the future paper requirements and the national interests of the Mekong Basin countries.

The fifth major objective of the pulp/paper part of this Study is to develop a course of action for detailed technical studies on kenaf fiber preparation and pulping that could be recommended as being worthy of future financial support by the Mekong Committee and/or other Governmental or international or private agencies. Such a program would take into consideration all the work that has already been carried on in various laboratories and mills in the world and would attempt to coordinate, influence, and direct future investigations by all scientists working on kenaf for paper pulp. The use of substantial pilot plant and laboratory facilities and a pulp/paper mill already in Thailand would be one central item in this planning and Study. An important advantage of utilizing these existing facilities for commercial trials would be to speed by several years the finalization of present technical investigations and the establishment of the major parameters necessary for the development of a successful commercial process for utilizing kenaf for paper pulp as outlined on a theoretical basis for the model mill in this Study.

- Acknowledgements

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Dr. Prachoom Chomchai, Director
Economic and Social Studies Division
Mekong Committee

Mr. Phot Inganinanda, Director
Trade Policy Division
Ministry of Commerce

Mr. Vichit Piyarom, Deputy Director
Division of Land Settlements
Public Welfare Department

Dr. Thomas L. Irving, Director
Mr. Louis A. Cohen, Deputy Director
Mr. James F. Hanks, Mekong Project Officer
Regional Economic Development Office
American Embassy

To the above and the officials listed in Annex IV the Consultants tender their sincere appreciation.

1. SYNOPSIS

This Pre-Feasibility Study discusses the establishment of a paper pulp industry in the Lower Mekong Basin using kenaf as raw material and aimed at providing a steady source of income to a substantial number of small farmers - some 20,000 families for each pulp mill unit - and at contributing towards the substitution of the paper pulp presently imported into the four riparian countries with domestically produced pulp.

Six primary potential project pulp mill sites have been located in the Basin area and, for Study purposes, a project mill unit capacity of 70,000 ADMT/year is assumed, requiring some 25,000 ha. and 80,000 ha. of South Asian Kenaf (Hibiscus sabdariffa) planting area annually for a whole stalk kenaf and kenaf bast ribbon pulp mill respectively, and about one-half that planting area for Western Hemisphere Kenaf (Hibiscus cannabinus) which, however, needs somewhat better soils.

Kenaf and allied fibers have, historically, been successfully produced in the Lower Mekong Basin countries, with Northeast Thailand being the world's largest kenaf production area with annual small holder plantings fluctuating between some 300,000 and 500,000 ha., and Study investigations show that ample kenaf for paper pulp supplies would readily become available, within economic transportation distance, for potential project mills at any one of the six primary sites, where mills at Site II near Ubon Ratchathani in Northeast Thailand and at Site III near Stung Treng in Cambodia would assume a regional character in that each could call upon raw material supplies from a three-country area.

Based upon a detailed Study evaluation of standard small holder kenaf textile fiber production methods in the Basin area (which involves stalk and bast ribbon water retting not required for kenaf for paper pulp production) and of the results of experimental and, so far, only limited kenaf for paper pulp pilot work carried out in the U.S.A., Europe and South Asia, it is concluded that, from the production and supply point of view, adequate quantities of kenaf whole stalk, chopped stalk and bast ribbon could readily be made available to the kenaf project pulp mills discussed herein. The raw material procurement areas within economic transportation distance and the procurement methods are discussed in depth for kenaf whole stalks for Mill Site I north of Khon Kaen and for kenaf bast ribbon for Mill Site II east of Ubon Ratchathani respectively, with the conclusions reached obviously applicable interchangeably for both sites and preference being given to procurement through the established kenaf fiber

balancing and trading channels rather than through a mill operated organization and with strong encouragement being extended to the rapidly expanding participation of farmers organizations in the raw material supply.

The Study further recommends the establishment of one or more pulp mill operated kenaf Demonstration Farms to serve as extension services, demonstration and, possibly, input supply centers to the small holder kenaf producers in their respective areas of coverage.

The estimated prices payable by the project pulp mill(s) for kenaf pulping raw materials are calculated on the basis of farm revenues from traditional kenaf textile fiber production in Northeast Thailand and of such revenues realized from other crops that can be grown on land suitable for kenaf for paper pulp production. These prices, delivered local collection center, are then established at US\$24.90/FDMT for kenaf whole stalks or chopped stalks and at US\$96.75/FDMT for kenaf bast ribbon. After the addition of the estimated purchasing and handling costs, the delivered mill yard gate cost is then calculated at US\$30.00/FDMT for kenaf whole stalks, at US\$29.50/FDMT for kenaf chopped stalks, and at US\$104.00/FDMT for kenaf bast ribbons.

Technical studies on kenaf for paper pulp started about 1950 with only four significant research investigations published by 1960. Since that time, however, and particularly in the last five years, there has been a quantum jump to a total of almost two hundred publications on kenaf pulping research from laboratories in many parts of the world. The information also includes a number of studies on the harvesting, transporting, and storing of kenaf for paper pulp and the effects of the storage conditions on the resultant pulp qualities and yields.

Analysis of the pulp strength test data from these reports has shown that the bast ribbon soda or sulfate (kraft) pulps are very similar in papermaking properties to the highest quality softwood sulfate pulps on the market. The kenaf whole stalk pulp is quite similar to softwood sulfite pulp and the hardwood sulfate pulps that are widely used in printing and writing papers. The kenaf woody core material pulp has lower tearing strength than the wood pulps and also the nonwood plant fiber bagasse and straw pulps manufactured commercially. Because of the low strength properties and the adverse drainage characteristics of its chemical pulps, the woody core material pulp would not be considered a suitable product for the Mekong Basin mill. It would, however, possibly serve as a low cost fuel and a source of fibrous raw material for the manufacture of newsprint, particleboard, or chemical by-products.

In this Study, a review of this technical information on pulping has been made. From the data, the parameters have been developed for the design of a paper pulp mill for the manufacture of kenaf whole stalk or bast ribbon bleached chemical pulp. A mill for pulping kenaf would be identical in design to a bagasse or straw pulp mill, with the exception of the equipment for fiberizing the kenaf for the wet cleaning process.

Consideration has been given to the cost comparisons for fiber from kenaf whole stalk with bagasse and hardwoods and bast ribbon with softwoods. As most of the cost of bagasse for pulp is based on replacing it with other fuel at the sugar mill, the availability of lignite in Thailand at a very favorable low price makes bagasse a much lower cost fibrous raw material than kenaf whole stalk. The mixed tropical hardwood sulfate pulps that will eventually be produced in large pulp mills in the South Pacific-Asia area will also have the competitive advantages of low wood costs as well as "economy of size" as compared to the kenaf whole stalk pulp mill considered in this Study.

In comparison to softwood bleached sulfate market pulps, the kenaf bast ribbon pulp would have a much higher fibrous raw material cost. An economic analysis has been made of the possibilities for mechanical separation of the bast ribbon at the pulp mill so that the woody core material can be used as fuel, pulp for newsprint, or for particleboard and the cost of the bast ribbon fraction could thereby be reduced.

Potential markets for kenaf pulp have been estimated, based on information concerning the importation of paper and paperboard and the productive capacities and pulp usages by paper mills in the Mekong riparian countries. Even with an anticipated low growth rate of only 3.5 percent annually in paper and paperboard consumption, it appears that, by 1980, the kenaf pulp could be absorbed by the local market and exports would not be necessary. However, if a large integrated pulp/paper mill were to be built using bamboo and bagasse in Thailand, a serious competitive constraint for local sales could develop for the kenaf pulp mill and a delay of another 5 to 10 years in building it might be required, unless the kenaf pulp is for export.

The project model mill has been based on a design for producing 200 ADMT/day or 70,000 ADMT/year of kenaf bleached soda or sulfate whole stalk or bast ribbon pulp. This is considered a minimum size of market pulp mill that would be economically viable. The two locations in the Mekong Basin judged to be the most suited for the pulp mill are in Northeast Thailand at Ubon Ratchathani and the Ubolratana Resettlement Area north of Khon Kaen. There are adequate sites and much of the required infrastructure which favor these locations.

In this Study, plans for the entire mill process and its operating parameters have been established. This includes the handling, storage, reclaiming, fiberizing, and wet cleaning of field dried baled kenaf received at the pulp mill. The problems of environmental control are discussed and a program to minimize pollution has been developed.

Detailed estimates have been made of production costs, capital requirements, profitability, and economic values of the project mill. The total capital requirements, including the entire mill, housing community, working capital, and all other costs for establishing the enterprise have been estimated to be US\$81,284,000 of which 33.87 percent would be local funds provided for all local expenditures and the rest would be foreign loans covering the foreign costs for the "turn key" mill.

The 15-year financial projection for the kenaf whole stalk bleached pulp mill shows that, if the product were sold delivered in Thailand for US\$450.00/ADMT, the present competitive price for imported hardwood bleached sulfate pulp, the project would have very good economic viability. The payback period would be 7.55 years. The average annual return on the basis of total investment would be 14.1 percent and on the basis of owners' equity would be 35 percent or 16.9 percent by the discounted cash flow method.

Because of its higher fibrous raw material cost, the kenaf bast ribbon pulp mill product would have to sell for US\$600.00/ADMT to achieve an equivalent economic viability with that of the whole stalk project. As this is about US\$130.00/ADMT above the present price in Thailand for imported softwood bleached sulfate pulp with which the kenaf ribbon pulp would compete, tariff protection for the local mill's product would require imposition of a 28 percent duty on imported softwood pulp.

The economic values of the kenaf paper project to the Mekong Basin area would be considerable. Many new industrial jobs would be created and the increase in agricultural production of the kenaf would furnish a large amount of new income to that sector. The financial analysis shows that, over the projection period, there would be an average net saving of foreign exchange of US\$23,153,000 annually.

The Study also details the required future developmental activities deemed necessary prior to large-scale kenaf based pulp and paper mill project implementation. From the raw material supply point of view, these will have to concentrate on yield improvement through variety selection and improved cultural practices, and on the establishment of optimum specific kenaf for paper pulp harvesting and field processing

methods, these aims to be achieved through the implementation of a combined research and pilot scale program, preferably organized along Demonstration Farm lines.

In the pulp/paper portion of this Study, it is pointed out that commercial production of kenaf pulps has not materialized as originally anticipated. It has been concluded that the production of commercial quantities of kenaf pulps for market and papermaking trials would be more meaningful than further laboratory research, because there is already sufficient technical information on the pulping of kenaf and other nonwood plant fibers to serve as the design basis for a mill.

However, in parallel with the commercial production investigations, useful research on kenaf could be carried on in certain areas that have not been thoroughly explored. This would cover comparative pulping evaluations of kenaf samples from the agro-economic research program, the comparative evaluation of bulk versus bale storage systems, the development of a system for separating bast ribbon from woody core material at the pulp mill, the separation of the two types of fibers by fractionation after pulping, and the manufacture of newsprint and particleboard from kenaf.

In a continuing investigation which might be made before a kenaf pulp mill is implemented, the agro-economic studies would be best carried out at or near one of the primary sites that have been located in this Study. Because of this, the logical choice for Executing Agency for further studies on kenaf paperpulp would be the Committee for Coordination of Investigations of the Lower Mekong Basin. Possible sources of supporting grants for further studies would be the United Nations Development Programme, the World Bank and Asian Development Bank, as well as Governments of the riparian countries.

The technical and management services of an independent consulting firm, experienced with nonwood plant fiber pulping, to conduct the commercial pulping and papermaking trials and marketing tests are recommended. Such investigations could possibly be carried out at the Siam Kraft Paper Co., Ltd. in Thailand and/or the United Pulp and Paper Co. in the Philippines. The laboratory facilities of these mills would be utilized for the production runs. In addition, laboratory investigations in conjunction with the future kenaf agro-economic studies could be carried on by the Research Division of the Department of Science of the Ministry of Industry in Thailand.

2. SUMMARY

CHAPTER I - THE USE OF KENAF FOR PULP AND PAPER

1. Early History of Kenaf as a Raw Material for Pulp and Paper (1950-1960).

Although used for food, animal forage, and fiber for many centuries, the history of kenaf for paper pulp begins about 1950. This is surprising when a similar fiber, jute in the form of bast fiber textile wastes, was used in earlier years for making high strength papers in the United States and elsewhere. Prior to 1960, there were only four or five technical reports relating to the pulping of kenaf. Most of these, published by the United States Department of Agriculture (USDA), were based on laboratory tests comparing kenaf with the pulping qualities of nonwood plant fibers already in extensive use. The interest in kenaf at that time was thus essentially that of a laboratory curiosity.

2. A Review of Worldwide Experience in Harvesting, Transporting, Storing and Pulping of Whole Kenaf and Kenaf Components for Paper Pulp

2.1. Introduction

Little has been published on harvesting, bulk transport, and storage of kenaf for paper pulp other than by the USDA. Investigations by most of the others have mainly been based on the assumption that field dried kenaf, either whole stalk or bast ribbons, would be baled or bundled and delivered to the pulp mill. Lack of information contributed some years ago to the failure to develop commercial production of kenaf in Florida by the USDA and also in several Latin American countries. The USDA, recognizing the pressing need for agro-economic studies on kenaf for paper pulp, has continued its research in this area.

2.2. Harvesting the Bast Fiber in Kenaf for Paper Pulp

The traditional procedure for the hand harvesting and retting of kenaf and similar bast fibers for textiles and cordage is well known. During the retting process, the bast fiber is freed of its incrusting organic materials which are to a great extent water soluble and degradable. At this point, the wet cleaned fiber would also make an ideal pulping material for the manufacture of papers with high physical strength characteristics. The laborious retting, however, is not only costly, but is not needed for pulp manufacture and can be eliminated entirely.

Wet cleaning of the bast ribbons separated by the farmer can be carried out much more easily and economically at the pulp mill than at the farm by retting. This would save about 40 to 45 percent of the total time the farmer now spends in growing the kenaf and preparing the bast fiber for the textile mill.

Even more of the farmer's time would be saved by also eliminating his ribboning operation which would then be carried out on whole stalk kenaf with suitable processes at the pulp mill. Efforts by the USDA to develop complicated combined harvesting and decorticating machines suitable for subsequent textile fiber production were not successful and their development was dropped when funds ran out. The basic hand-fed, mechanical ribboning machines that have been successfully used in commercial operations on kenaf can nevertheless be expected to suffice in moderate-cost labor areas for producing bast ribbon at the farm level for a pulp mill. Various companies and other organizations are continuing the development work on ribboning machines or processes.

Although mechanization of kenaf ribbon production at the farm level is necessary or advantageous in some locations, this will not be required under the present agricultural system in the Mekong Basin before a pulp mill can be planned.

2.3. Harvesting Whole Stalk Kenaf for Paper Pulp

For the Mekong Basin area, the traditional procedure for hand harvesting kenaf whole stalk before retting it can be used in preparing field dried material for collection, baling, and shipment to the projected pulp mill.

Field studies in the United States by the USDA and others for utilizing whole stalk kenaf for paper pulp have included mechanical harvesting, transportation, bulk storage, and handling because hand harvesting would be out of the question.

At the First Conference on Kenaf for Pulp at Gainesville, Florida, in 1967, some very significant studies were reported. One study covered mechanized forage harvesting and storage of green kenaf ensilage on a semi-commercial scale in connection with a full scale pulping trial at Hudson Pulp and Paper Company.

By a 1975 study by the USDA it was recognized that forage harvesting of field dried stalks requires a heavy expenditure for energy and that the systems for handling and storing green kenaf appear to be too expensive to be applicable at the present time. It was indicated that much continued research would be required to develop satisfactory and economical equipment for the mechanized harvesting and handling of kenaf for paper pulp.

2.4. Transporting Whole Stalk Kenaf for Paper Pulp

Field work done on transporting whole stalk kenaf in bulk form has not been very satisfactory. The methods used were expedients and can not be compared to the sophisticated and successful systems that have been developed for the mechanized harvesting and bulk transportation of sugar cane which can readily be applied to kenaf.

Economists and agronomists of the USDA have published studies on means and costs for bulk transportation of chopped kenaf that would be applicable where labor costs are high and large farms could be developed. However, such mechanized systems are not considered to be necessary for producing the kenaf for a pulp mill project in the Mekong Basin under existing conditions. Hand harvesting the field dried whole stalk or ribboning the green stalk and field drying the bast ribbon before baling and transporting the kenaf to the pulp mill are expected to be economical systems that will be satisfactory for the production of pulp.

2.5. The Storage of Kenaf for Paper Pulp

2.5.1. Introduction

Since kenaf is an annual crop, it would have an important advantage for pulp mills in developing nations lacking adequate supplies of standing pulpwood. The generation or more required to establish a forest plantation and the long term capital requirements of forestry can be avoided by using kenaf.

However, as compared to tress which can be "stored" standing and growing in the forest until needed, kenaf, which must be harvested annually, will have to be stored for as much as eight months or longer between harvests. It is very important that storage conditions preserve the physical strength properties of the pulps and prevent an excessive loss of fiber suitable for papermaking. Fortunately, the storage of other nonwood plant fibers, such as bagasse for papermaking, has been successful for many years so that it is anticipated that kenaf can be handled similarly.

In the case of whole stalk kenaf, as opposed to kenaf bast fiber material, there can actually be storage for some months by leaving the stalks standing in the field after being frost killed (in the temperate zone) or after maturity resulting from photoperiodism (in the tropics). Although the highest stem weight yield was found to result when the harvest was immediately before or after frost, studies by the USDA have shown that the decrease in yield of total stem weight for several months after that time resulted from a loss of water soluble and fermentable sugars, gums, and other nonfibrous materials. This is due to leaching by rain of the stalks standing in the field or other physical and chemical changes which take place in the kenaf. During this period, the cellulose, pentosan, and lignin percentages actually increase, and it was determined that the kenaf can be left standing in the field for at least two months after maturity before there is any loss of yield or quality of fiber for papermaking.

2.5.2. Bulk Storage of Kenaf

Studies on systems for bulk storage of green whole stalk kenaf and their effects upon pulp properties were started by the USDA in 1965. Storing the green kenaf as ensilage for several months and then wet cleaning the fiber before pulping were found to be satisfactory procedures. The commercial pulping trials on kenaf made at Hudson Pulp and Paper Company about that same time used whole stalk silage to which molasses had been added in an attempt to simulate the conditions for lacto-bacteria formation which exist in the Ritter storage system for hydraulically piled bagasse where anaerobic conditions prevail and complete papermaking fiber preservation results.

The USDA also determined that, when chopped green kenaf was stored in large piles at a moisture content above 35 percent, the temperature of the kenaf rose and deterioration resulted. A number of storage procedures were evaluated and found to be suitable for kenaf. Storage of green kenaf silage under anaerobic conditions such as in a silo or pit, submerged in water, or in a plastic cocoon was found to furnish adequate preservation. Artificial drying and storage under cover was successful but uneconomical. Daily immersion of samples in water followed by exposure to aerobic conditions resulted in deterioration of the kenaf, whereas storage submerged in water preserved it and improved the pulping characteristics by removing much of the pith and parenchyma cells and the soluble sugars and gums.

USDA studies also showed that dejuicing the green kenaf and also removing the foliage before storage improved the resultant whole stalk pulp quality. Wet cleaning of the stored fiber before pulping was

advantageous in all cases; it lowered the chemicals required for cooking and bleaching and produced a stronger pulp with better drainage rates than in tests where wet cleaning was not done.

The test data by the USDA indicated, however, that bale storage of field dried kenaf, as would be used in the Mekong project pulp mill, would be just as suitable as the best of the bulk storage systems evaluated on green kenaf. Therefore, it is emphasized that bulk storage systems are not being considered for the Mekong project pulp mill which will be based primarily on kenaf which has been field dried before baling and storing in covered ricks.

2.5.3. Storage of Baled or Bundled Kenaf

Bale storage of nonwood plant fibers, such as bagasse and straw, has been used commercially for many years. USDA investigations have shown that, when baled at a moisture content below 25 percent and stored in covered ricks, satisfactory preservation of kenaf fiber quality and maintenance of pulp yield result. Exposure of piles of bales to the elements was found to have a deleterious effect on the top bales. Although the research comparisons in the reports were not technically valid, cost data comparisons for pulps produced from protected baled kenaf with pulps from green kenaf from bulk storage showed the former cost less to produce and consumed less fibrous raw material than the latter pulps.

2.6. Review of Studies on Kenaf for Paper Pulp (1950-1975)

2.6.1. Introduction

There were only four or five significant technical articles on the pulping of kenaf prior to 1960, but by the latter half of the 1960's the literature on this subject began to expand rapidly. Attendees at the First World Conference on Kenaf in Havana in 1958 indicated a developing interest in this crop for paper pulp. At the Second International Kenaf Conference at Palm Beach in 1964, there were three papers on pulping. By 1967, the interest in kenaf was such that a committee of the Technical Association of the Pulp and Paper Industry (TAPPI - U.S.A.) presented the First Conference on Kenaf for Pulp in Gainesville, Florida. By 1970, the interest in pulping nonwood plant fibers, including kenaf, had continued to increase so that TAPPI established a committee - the Nonwood Plant Fibers Committee - to conduct annual programs on all aspects of pulping these fibers. Since the beginning of these meetings, this committee has published 53 technical papers, 15 of which have been on kenaf.

These TAPPI papers are only an indication of the large number of published studies on paper pulp from kenaf. Annex III listing the Bibliography for this review gives about 200 such references. This listing does not cover the hundreds of technical reports on the growing of kenaf and its processing for textile uses.

The research information reviewed in the main text of this Study has been used as a basis for establishing the agronomic, economic, and technical parameters for the proposed pulp mill. The review of these investigations is found in Sections 2.6.3. through 2.6.9. of Chapter I.

2.6.2. Interpretation of Technical Data Reviewed

Caution has been found necessary in correlating the data on kenaf pulping from so many different laboratories. In addition to the normal differences in testing procedures, equipment, and methods of reporting results in publications, it has only recently been recognized that the variations in pulps, resulting from the systems of raw fiber preparation, are in many cases not clearly explained or related to the techniques of the investigations. This review has shown that it is most important to know conditions or treatments the kenaf may have been subjected to from the time it reached maturity, or was harvested, until it was fed into the digester for the pulping test. In many of these investigations, the history of the treatment of the kenaf samples and the raw fiber preparation steps have not been clearly stated, if at all, and this is responsible for some of the confusion and differences with regard to pulping yields and other data.

Therefore, future investigations of kenaf pulping should include the complete background of the harvesting, storage, and raw fiber preparation of the sample up until it enters the digester.

2.6.3. Studies on Kenaf for Paper Pulp by the United States Department of Agriculture

Much technical information has been published by the USDA on the growing, harvesting, storage, and pulping of kenaf. This work, over the last 10 years or more, has been an outgrowth of studies beginning in 1943/1944, and terminating about 1965, to assess the production of kenaf bast fiber for textile and cordage purposes in the United States.

As early as 1956, the Agricultural Research Service and the Northern Regional Research Laboratory of the USDA undertook a screening program for the major species of fibers in the world. Its purpose was to identify those plants which could be grown as an annual crop

and whose fibers would be the most promising for paper pulp. The earliest report covered approximately 1,200 samples, of which about 850 were evaluated from the almost 500 species of plants received. The results showed the best nonwood plant fibers for paper making to be kenaf, bamboo, crotalaria, hemp, sesbania, and sorghum. Of these, kenaf received a high rating in all categories for paper pulp production.

Investigations of additional species and samples were then carried out in comparison with the most promising fibers already screened by the USDA. Although kenaf whole stalk chemical pulp was not rated the highest for physical strength properties, it was concluded that kenaf would be the prime potential nonwood plant crop for pulp because of its high growth productivity and other favorable agronomic characteristics in addition to its pulping qualities.

The agronomic and pulping investigations published by the USDA have been greater in scope than those of all others. The USDA has studied not only the agronomic and economic aspects of growing kenaf for pulp but also its mechanized harvesting, storage in all types of crop ensilage and bale systems at the full range of moisture and preservation conditions, the effects of precleaning the fiber before pulping, and pulping and bleaching of the kenaf components under all the conditions and chemical treatments known in the pulping industry. Practically every type of chemical and mechanical pulp has been produced from kenaf. Both experimental and semi-commercial papermaking runs have been made with kenaf pulps, with most of the trials oriented to produce kenaf whole stalk bleached chemical pulp that would substitute for bleached hardwood sulfate pulp.

This work is so comprehensive that it can serve as a sound basis for the next required step in the development of kenaf for paper pulp. This is the production of kenaf pulps of both types for market and papermaking trials on a commercial scale preparatory to the final feasibility study for a kenaf paper mill in the Mekong Basin.

2.6.4. Other Investigations and Reports on Kenaf for Paper Pulp in the United States

A number of companies, technical associations, and others have worked on kenaf pulping in the United States. These investigations are reviewed in Subsections 2.6.4.1. through 2.6.4.13. of Chapter I. The most important work has been done by the A.B. Dick Company, the Bauer Brothers Company, the TAPPI ad hoc Committee on Kenaf and Related Raw Materials (and its successor, the TAPPI Nonwood Plant Fibers Committee), J.E. Atchison, the Black Clawson Company, Eastex, Inc.,

Kimberly Clark Corporation, the University of Florida Pulp Laboratory, Hudson Pulp and Paper Corporation, Herty Foundation, Champion Papers, Inc., and Eastman Kodak Company.

2.6.5. Work on Kenaf Paper Pulp in Nations Bordering on the Western Pacific Ocean

This research has been reviewed in Subsections 2.6.5.1. through 2.6.5.3. of Chapter I.

In Australia the Commonwealth Scientific and Industrial Research Organization (CSIRO) has been growing kenaf and other crop fibers for pulping studies. Also finding that kenaf has the greatest potential of the nonwood plant fibers for making paper, they have investigated the economics of supplying kenaf in bulk to Japan. Their reports have covered the pulping by several chemical processes of the whole stalk and its components separately, kenaf newsprint, improving the raw fiber for pulping by cleaning and dejuicing it, mechanical processes for separation of core material and bast ribbon, and removal of slow draining fines from the pulp by screening.

In Japan, the Oji Paper Company has made experimental paper machine trials with kenaf chemical and mechanical pulps, and the Toyo Pulp Company claims to have developed an automatic-feed kenaf ribboning machine.

2.6.6. Studies on Kenaf for Paper Pulp in Europe and West Asia

Kenaf pulping research in these areas has been reviewed in Subsections 2.6.6.1. through 2.6.6.6. of Chapter I.

Kenaf has been grown for pulping trials in Italy by the large paper manufacturer, FaBoCart, S.A. Whole stalk as well as kenaf stem components have been pulped for use in cultural paper grades ranging from newsprint to coated printing grades.

In the Tashkent region of the U.S.S.R., where kenaf for textile purposes is grown, the woody core material has been pulped to obtain chemical cellulose pulp for use in lacquers.

At Tvornica Papira Rijeka in Yugoslavia - the world's only full scale pulp and paper mill using kenaf - the bast ribbon is used, together with some core material, to manufacture cigarette paper of high quality. This paper was formerly made from hemp and flax waste fibers at this mill.

Organizations in France have investigated the possibilities of kenaf for paper pulp over the past 15 years. The Ecole Francaise de Papeterie has made studies for private clients. Le Centre Technique de l'Industrie Papetiere compared kenaf for pulp with pulps from sorghum, hemp, and Provence reeds. Kenaf was found to be unsuited for agricultural exploitation in France because the plant would not ripen and produce seeds under the climatic conditions found there. The pulping investigations showed that the physical strength properties and the drainage characteristics of the whole stalk pulp could be improved by fractionating it to remove the fines. In comparison with Provence reeds, however, the resultant low yields in both the field and pulp mill and the high cost of production of the raw kenaf fiber ruled out its use in that area.

Cellulose d'Acquitaine studied the pulping of kenaf in France and, in agreement with the other investigators there, judged that there are too many problems associated with kenaf for pulp for it to become a commercial crop in that country.

2.6.7. Investigations on Kenaf for Paper Pulp in Latin America

Countries in Latin America have been interested in or have used kenaf for textile fibers, so interest has followed in its use for paper pulp. The review of these investigations is given in Subsections 2.6.7.1. through 2.6.7.3. of Chapter I.

The Cuban Sugar Cane Derivatives Research Institute (ICIDCA) has prepared kenaf chemical cellulose pulp for acetylation.

The Laboratorios Nacionales de Fomento Industrial in Mexico studied kenaf bast fiber pulps and found them to be higher in strength characteristics than pulps from yucca, henequen decorticating waste, bamboo, bagasse, hardwoods, and softwoods.

The Department of Forestry in Argentina has made agronomic studies of kenaf from various parts of the nation for pulping. Because of the high strength properties of the pulp from the bast component of the whole stalk, these investigations employed procedures to separate the stalk components both before and after the cooking, whereby two very different pulp fractions were produced.

2.6.8. Development of Kenaf Paper Pulps in Nations Bordering on the Indian Ocean

Several studies on kenaf pulp have also been reported for these countries where jute is grown and has been considered for many years as being a high quality fibrous raw material for papermaking. These studies are reviewed in Subsection 2.6.8.1. through 2.6.8.9. of Chapter I.

In Bangladesh, the former Eastern Regional Laboratories (P.C.S.I.R.) studied the manufacture of printing and writing papers using both jute stick and kenaf woody core material pulps together with bamboo pulp for the high strength fiber in the furnish.

Rumors of production of paper from kenaf in India could not be traced to any commercial operation. However, studies on kenaf whole stalk pulps at J.K. Paper Mills resulted in an estimate that kenaf bleached whole stalk pulp would cost more to produce than would bamboo pulp. At Sirpur Paper Mills, Ltd., extensive laboratory trials have been made to produce pulps from kenaf and its stem components. As compared to bamboo and tropical hardwoods, the data indicated the kenaf whole stalk and woody core material would not be a primary choice for fibrous raw material to make chemical pulp.

Pulping tests to produce chemimechanical pulp for corrugating material and chemical pulps for wrapping paper and bleached papers were made at the Forest Research Institute in India. Studies at the Indian Technological Research Laboratories determined that kenaf core material pulp was not as satisfactory as that from jute sticks. However, the Indian Jute Technical research Laboratory found that kenaf core material left from the retting process could be used to prepare chemical cellulose pulp for nitrating.

The Eastern Paper Mills Corporation in Sri Lanka seems to have come nearest to practical commercial use of kenaf whole stalk bleached pulp as a result of test runs made in each of the past three years. In this company's pulp mill, which produces straw pulp, several large scale runs have been made in which kenaf pulp was used to substitute for imported softwood bleached sulfate pulp usually mixed with straw pulp to produce printing and writing papers. Reports have been issued by the researchers from this mill on the agronomic and pulping aspects of kenaf. They found that, while the bleached kenaf pulp was superior to straw pulp and could replace the softwood pulp in the furnish, the field yields of kenaf whole stalk so far achieved were much lower than would be required to compete in cost with plantation softwoods. This mill has also produced linerboard experimentally from unbleached kenaf chemical pulp and chemimechanical pulp that could be considered for use in newsprint.

2.6.9. Developmental Work on Kenaf Paper Pulps in Countries within the Mekong Basin Area

The field survey in Thailand for the present project found that considerable work has been done there on kenaf for paper pulp. The review of available information is given in Subsections 2.6.9.1. through 2.6.9.5. of Chapter I.

There are apparently four well equipped pulp/paper laboratories in Thailand, including the one at the Siam Kraft Paper Co., Ltd. Studies on kenaf pulping have been carried out in the Department of Science of the Ministry of Industry in Bangkok and at the laboratory of the Royal Department of Forestry. It is also reported that Kasetsart University's School of Forestry has a pulp/paper laboratory.

In addition to the kenaf pulping activities at these institutions, there have been three pulp mill projects promoted in Thailand in the last six years which were based wholly or partially on using kenaf whole stalk or wastes from bast fiber production.

The earliest of these projects was that of the United Pulp and Paper Company, Ltd. (UPPC) which was discontinued when the Thailand Board of Investment certificate for promotion expired in 1974. Feasibility studies for this project were made by Associated Consultants, Ltd. of Bangkok and kenaf pulping trials were made in the laboratories of several pulp and paper machinery manufacturers in Europe as well as in conjunction with the Applied Scientific Research Corporation of Thailand (ASRCT) at the Bang Pa-In mill. On the basis of these tests, it was proposed that both bleached and unbleached grades of kenaf whole stalk pulp be manufactured in Thailand.

A second project to manufacture kenaf whole stalk bleached pulp is now being developed by the Phoenix Pulp and Paper Co., Ltd. This is to be located near Khon Kaen in the Northeast of Thailand within the Mekong Basin. It has been reported that full scale pulping, bleaching, and papermaking runs using Thai whole stalk kenaf have been made for this project at the Ballarpur Paper & Straw Board Mills, Ltd. in India.

The third promoted project, that of the Sri Ayudhya Pulp Co., Ltd., is listed by the Board of Investment as using kenaf waste along with other nonwood plant fibers for pulping. Detailed information on this project was not available for review.

Apart from its work on the original UPPC project in the laboratory of the Royal Forestry Department and at the Bang Pa-In mill, the ASRCT has carried out numerous investigations in which various types of pulps have been prepared. Studies include 100 percent kenaf pulps or those from admixtures with woods or other nonwood plant fibers available in Thailand. Unfortunately, the technical reports on the work of the ASRCT on kenaf pulps were not made available for this review. However, the information in them would not change the general conclusions or affect the parameters of this Study.

In the field survey for this Study, the pulping facilities of the Fiber and Paper Laboratory, Research Division, Department of Science, of the Ministry of Industry (Thailand) were discussed. Excellent testing equipment was furnished for this laboratory in 1964 by the United Nations Development Programme (UNDP) and the buildings, services, and personnel were supplied by the Government of Thailand. The extensive pulping studies made by this laboratory have included such raw materials as woods, kenaf, fibrous agricultural wastes, and other nonwood plant fibers found in Thailand. The experience of the technical staff of this organization in pulping kenaf would be very valuable in carrying out some phases of the research work on kenaf pulping which has been recommended for the Mekong Basin project.

3. The Physical Strength Properties of Kenaf Pulps Compared to Other Major Papermaking Fiber Pulps of the World

3.1. Introduction

Most of the studies on kenaf pulping and bleaching have been at the laboratory level. Particularly in the case of the whole stalk kenaf chemical pulp, there is a lack of commercial-scale operating data that would serve as the basis for building the mill and selling the products considered in this Study. There is a need for commercial quantities of pulps for market studies and trials so that the physical strength properties and papermaking characteristics of the kenaf pulps, used for up to 100 percent of the fibrous furnish, can be established for all major grades of paper using full chemical pulps. It is most important that such pulps be produced with the optimum strength properties and best drainage characteristics that would result from the use of a wet cleaning system for the fibrous raw material and the pulping and bleaching of the pulps in the continuous systems used for other nonwood plant fibers in commercial practice.

3.2. Comparison of Laboratory Pulp Strength Test Data for Kenaf Paper Pulps with Other Nonwood Plant Fiber and Wood Chemical Pulps

In consideration of kenaf paper pulp for its papermaking qualities, an analysis has been made for this review of the data published or furnished by laboratories from several countries. The test results were averaged for the kenaf whole stalk, bast ribbon, and woody core material pulps and compared with the average data on strength tests for full chemical pulps made from hardwoods, softwoods, and other nonwood plant fibers used for papermaking.

The comparison of pulp test data uses a simplistic expression of the laboratory refining-strength curves as shown in Figure I.1. of the main text of this report. (A copy of this is included as an annex to this summary.) This method for comparing the strength of pulps from the various fibrous raw materials is based on the relationship between the two physical tests for tearing strength and bursting strength at various levels of freeness on the laboratory beater curves.

The interpretation of the respective locations of the curves in Figure I.1. is that the stronger pulps used in conventional papermaking, such as the softwood sulfate pulps, have both high tear and burst factor values. Pulps of medium strength properties with lower tearing strength are the esparto soda pulp, hardwood sulfate pulps, bamboo sulfate pulp, and softwood sulfite pulp. The pulps of low tearing strength are those of the major nonwood plant fibers in commercial use, such as bagasse and straw soda pulps, which are useful and perfectly acceptable for many grades of paper where stronger softwood sulfate pulps can be added to give the required tearing strength properties to the finished product.

It can be seen from these data that the pulped bast ribbon yields a product comparable in strength properties to the best of the softwood sulfate pulps on the market.

The refining-strength test curve for the whole stalk kenaf pulp shows it to be somewhat higher in the relationship of strength properties than the market hardwood sulfate pulp which is widely used in the major grades of printing and writing papers, sanitary papers, etc. However, the kenaf whole stalk soda pulp, because of its content of fines, has the detrimental property of a much lower initial freeness test than the other pulps except that for straw. The fines affect the sheet properties as well as the speed of the paper machine. This pulp is also very sensitive to refining which also slows the drainage characteristic further. However, this may not be a drawback for all grades of paper when compared to the other paper pulps with higher initial freeness values.

The kenaf woody core material soda pulp has very low tearing strength properties and very poor drainage characteristics for use in conventional papermaking furnishes. Its use in any appreciable percentage in the fibrous furnish for most grades of paper would be ruled out where high speed production is required. The papers that would be suitable products when containing very much of this pulp would be limited in number. For this reason, the woody core material from kenaf should only be considered for use as a fuel, for the manufacture of mechanical-type pulps for newsprint and low grade printing papers, for semichemical pulps for corrugating medium, for particleboard, or for chemical by-products.

Therefore, the conclusion that can be drawn from these data for the strength properties of kenaf pulps in comparison with other pulps is that the bast ribbon soda or sulfate pulps would be excellent substitutes for the high strength softwood sulfate pulps for most grades of paper in which they are used.

The strength properties of the kenaf whole stalk soda or sulfate pulps are as good or better than the short fibered wood pulps and nonwood plant fiber pulps now in production. An improvement in drainage characteristics of the whole stalk chemical pulps, however, may be required before they become interchangeable with other market pulps.

The woody core material of kenaf is not suitable for use in producing the chemical grade of paper pulp because of its detrimental drainage properties. It should, however, receive proper consideration for its value as fuel or for the manufacture of newsprint and particleboard in any further studies for a Mekong Basin project pulp mill involving kenaf.

4. The Value of Kenaf as a Raw Material for Paper Pulp Compared to Sugar Cane Bagasse and Wood on a Worldwide Basis

4.1. Introduction

It is important to recognize that a comparison of the costs of the various fibrous raw materials used in papermaking is not valid unless consideration is given to final pulp product yields and delivered fibrous raw material cost on an equivalent oven dry basis for each material. In addition, there are differences in processing costs, equipment investment, pollution control costs, fuel and power consumption, economy of size for the mill, and other factors that enter into the final product cost. These can be quite variable, depending upon the fiber pulped. The true costs of using kenaf for paper pulp would include these considerations when the competitive costs of other

fibrous raw materials are discussed. For that reason, a full feasibility study for the pulp mill together with an exact determination of the price the product will bring in the market is required to determine the economic viability of the project. Although the cost of the kenaf fibrous raw material, in comparison to the fiber that would be available to other pulp mills, is important, it is only one of several factors that have been found necessary for investigation in this Study.

4.2. The Cost of Kenaf Whole Stalk in Comparison with Bagasse and Hardwoods as Fibrous Raw Materials for Paper Pulp

The major nonwood plant fiber raw materials competitive, on a technical basis, with whole stalk kenaf for pulp in Thailand are bamboo and sugar cane bagasse. Bamboo is outside the scope of this Study but bagasse has a great potential for future increased usage in this market area for the proposed Mekong Basin pulp mill's products. It is considered to be a strongly competitive raw material to kenaf whole stalk for paper pulp.

Bagasse is a unique fibrous raw material for papermaking in that it is an agricultural residue of cane sugar production. Therefore, it carries no fixed cost for land to grow it or the labor to harvest and get it through the sugar mill. Its value, therefore, bears no relationship to a cost of "producing" the bagasse but is related directly to the cost of replacing it with other fuels at the sugar mill, where the bagasse is now used for fuel. There must also be added the cost of moist depithing and transporting the bagasse to the pulp mill together with some small premium payment for profit to the sugar mill.

In this Study it has been considered that oil is available as replacement fuel to the sugar mill at ฿1,800/MT (US\$90.00/MT) and lignite is also available at ฿310/MT (US\$15.50/MT) delivered. On this basis, when furnace efficiencies for burning the different fuels and the bleached pulp product yields and other pertinent factors of cost are considered, the following comparison results:

Case	Fibrous Raw Material	Replacement Fuel	Estimated Fibrous Raw Material Cost Based on Bleached Pulp Product	
			(฿/ADMT)	(US\$/ADMT)
1	Bagasse	Oil	1,554	(77.70)
2	Bagasse	Lignite	910	(45.50)
3	Whole Stalk Kenaf*	-	1,865	(93.25)

* Note: Includes cost of fiberizing kenaf.

In order to equal the cost of bagasse based on its replacement with oil, the field dried kenaf whole stalk bales would have to be delivered to the pulp mill for £494/MT (US\$24.70). If lignite is the fuel, in comparison with bagasse the pulp mill could pay only £275/MT (US\$13.75/MT) for the field dried kenaf whole stalk instead of the price estimated in this Study as being £600/MT (US\$30.00/MT) delivered.

These estimated fibrous raw material costs for kenaf and bagasse for paper pulp in Thailand should be considered in relation to recent costs for hardwood for pulping in various parts of the world.

<u>Item</u>	<u>Estimated Fibrous Raw Material Cost Based on Bleached Pulp Product (US\$/ADMT)</u>
Mixed tropical hardwood chips (South Pacific-Asian mill)	55.00
Mixed tropical hardwood chips (at Dock in Japan)	120.00
Eucalyptus chips (from Australia delivered to Japan)	160.00
Hardwood chips (delivered to pulp mill)	
U.S.A.	100.00
Sweden	110.00
Finland	130.00

It must be emphasized that, although the bagasse and kenaf pulps in Thailand have a basis for comparison with regard to fibrous raw material cost, they can not be compared with these wood costs for a ton of product for the reasons explained previously. For example, the South Pacific-Asian mill that would pulp mixed tropical hardwood chips, and probably market some of the pulp in the Mekong riparian countries, would have a great advantage of "economy of size" because it could be expected to produce three or four times as much pulp as the mill considered for this Study. It would also utilize low cost wood waste to produce the lower amount of power and steam required per unit of product by the hardwood pulp mill. In the case of the wood chips for Japan, their industry has been willing to pay the higher costs, which include freight on about four times the wet weight of raw material for that of the pulp produced, to provide employment within the country and to reduce imports of hardwood pulp from other high cost producing countries.

Considering the economies and high land and labor costs of the developed countries that are producing hardwood market pulps, the fibrous raw material costs are actually relatively low because of the high degree of mechanization and the efficiencies that have been achieved in pulpwood production, transportation, and processing. In the case of Thailand and some of the other developing countries, the agronomic system for providing kenaf whole stalk to the pulp mill as envisioned for this project is fully dependent upon plentiful and low cost agricultural labor. The use of marginal land unsuited for mechanized farming and the production of more valuable crops also favors a low cost for kenaf. If these economic and other conditions where kenaf is now grown at low cost do not continue, kenaf could become a relatively much higher cost fibrous raw material than bagasse in Thailand. Eventually, even hardwood pulpwood plantations might become a lower cost source of raw material than whole stalk kenaf for the Mekong Basin mill. These possibilities will have to be considered in the full scale feasibility study and long range planning for any kenaf pulp mill.

4.3. Comparative Costs of Kenaf Bast Ribbon and Softwoods as Fibrous Raw Materials for Paper Pulp

Kenaf bast ribbon soda or sulfate pulps are technically interchangeable in papermaking with the softwood sulfate (kraft) pulps because of the comparable physical strength properties. In the Mekong riparian countries' papermills, the bast ribbon pulp would not be required as a substitute for the lower strength full chemical pulps from kenaf whole stalk, bagasse, or hardwoods, but would be used only in those grades of paper requiring the high tearing strength pulps for all or part of the furnish.

The mills in the developed countries of North America and Scandinavia, where most of the high strength market softwood pulps are produced, have the advantages of "economy of size" in comparison to that of the mill projected in this Study. There are many adverse factors such as high labor, sales, transportation, and handling costs for the softwood sulfate pulps from the developed pulp producing countries supplying the riparian countries' paper mills. These aspects, together with steadily increasing costs for fuel and wood for these mills, make it worth considering the use of kenaf bast ribbon for pulp in the Mekong Basin.

In comparing the cost of manufacturing pulp from kenaf bast ribbon with the cost of producing softwood sulfate pulp, the following values for fibrous raw material costs were determined in 1975 during this Study:

<u>Item</u>	<u>Estimated Fibrous Raw Material Cost Based on Bleached Pulp Product (US\$/ADMT)</u>
Softwood delivered to mill in interior of B.C., Canada	
Sawmill chips	60.00
Pulpwood	90.00
Softwood chips from West Coast USA (delivered to Japan)	180.00
Softwood from Southern USA	
Pulpwood (delivered to mill)	88.00
Chips (delivered to Sweden)	190.00
Domestic softwoods (as chips)	
Sweden	145.00
Finland	170.00
Kenaf bast ribbon (delivered to Mekong Basin mill)	237.70

The data show that, to be competitive on the pulp market with bleached softwood sulfate pulp in the South Pacific-Asia area, the kenaf bast ribbon for bleached pulp would have to cost about ¥3,000/ADMT (US\$150.00/ADMT) of product. This would be equivalent to paying ¥1,313/MT (US\$65.65/MT) for field dried bast ribbon delivered to the mill rather than the ¥2,080/MT (US\$104.00/MT) estimated as the cost in the agro-economic sections of this Study.

Three theoretical possibilities for lowering the cost of kenaf bast ribbon for pulp production have been examined in this Study. Cases 1 and 2 are based on the development of dry or wet process systems for separation of the bast ribbon from the woody core material when field dried kenaf whole stalks would be delivered to the pulp mill at the price of ¥600/MT (US\$30.00/MT), as determined in the agro-economic sections of this Study. Case 3 is based on the separation of the two stalk components by the farmer and their delivery to the mill in baled, field dried condition.

Case 1. A dry fiberizing process would be used at the pulp mill to separate the bast ribbon from the woody core of the field dried kenaf whole stalk. The core would be used for fuel at the pulp mill.

Case 2. A wet fiberizing process would be used at the pulp mill to separate the bast ribbon from the woody core material. The core material would be pressed to a 50 percent moisture content and used for fuel at the pulp mill.

Case 3. In this situation, it is assumed that the income to the farmer from the bast ribbon at the price of ₪2,080/MT (US\$104.00/MT) delivered to the mill would make it advantageous for him to supply the proportional amount of the woody core material that he separates so that it can be delivered as field dried material to the pulp mill for ₪400/MT (US\$20.00/MT) for use as fuel.

The detailed calculations for the hypothetical Cases 1, 2, and 3 have been summarized as follows:

<u>Case</u>	<u>Situation</u>	<u>Fuel Replaced</u>	<u>Estimated Fibrous Raw Material Cost Based on Bleached Pulp Product</u>	
			<u>(₪/ADMT)</u>	<u>(US\$/ADMT)</u>
1	Dry Separation Process, Core Used for Fuel	Oil	1,833	(91.65)
		Lignite	3,084	(154.20)
2	Wet Separation Process, Core Used for Fuel	Oil	3,249	(162.45)
		Lignite	4,384	(219.20)
3	Separation by Farmer, Core Used for Fuel	Oil	3,386	(169.30)
		Lignite	5,077	(253.85)
-	Kenaf Bast Ribbon Cost in this Study (at ₪2,080/MT)	-	4,754	(237.70)
-	Kenaf Bast Ribbon Cost Considered Competitive with Softwood for Pulp (at ₪1,313/MT)	-	3,000	(150.00)

With regard to Case 3 above, rather than the ¥400/MT (US\$20.00/MT) used here for the delivered cost of kenaf woody core material, the cost would have to be ¥340/MT (US\$17.00/MT) to compete with lignite on a straight fuel-into-steam value basis.

These data from the calculations for these hypothetical cases show the importance of considering the waste woody core material for fuel, particularly if oil would be the only fossil fuel available to the project mill. In Case 1, where the two components would be separated by a dry process at the pulp mill, the cost of the kenaf bast ribbon could be lowered by 35 percent if the proportional amount of the core material were used as fuel to replace the low cost lignite available and expected to be used for the pulp mill in Thailand. This is based on the assumption that the 195 percent excess woody core material, which would theoretically be available above that needed for the fuel requirements of the pulp mill, would be used instead of lignite to generate steam and/or power for other industries nearby or power for the national grid.

As an alternative to its use for fuel, part or all of the woody core material could be considered for manufacturing particleboard or mechanical pulp for newsprint at the same mill. The woody core material separated by the hypothetical dry process, if not used for fuel to replace lignite, could be used to produce the equivalent of about 653 ODMT/day of mechanical pulp costing only ¥554/ODMT (US\$27.70/ODMT) of pulp for fibrous raw material. Assuming that the mechanical pulp were 85 percent of the fibrous furnish for newsprint and that 128 ADMT/day of kenaf bast ribbon slush semi-bleached soda pulp (64 percent of the project pulp mill's productive capacity) could be used for the high strength chemical pulp furnish component, there could be a newsprint production of 810 tpd. or 283,500 tpy. from the woody core material theoretically available from the manufacture of 200 tpd. or 70,000 tpy. of kenaf bast ribbon bleached pulp.

In Case 2, the use of a wet fiberizing process, as compared to a dry or hand separation of the two kenaf stalk components, results in a loss to the effluent system of some of the solids which have fuel value. In addition, the pressed kenaf woody core material at 50 percent moisture content has a dry basis fuel-into-steam efficiency of 65 percent as compared to 75 percent efficiency at the field dried moisture content of 12.5 percent. For these reasons the economics of the wet separation process are not as favorable for lowering the cost of bast ribbon as the dry process. However, the economics of producing mechanical pulp from the core material for newsprint would remain the same as for the dry separation process.

In Case 3, when the farmer collects the proportional quantity of core material from the bast ribbon production for the mill and it is delivered to the mill baled and in field dried form, its cost for fuel only at £400/MT (US\$20.00/MT) is higher than the cost of lignite it would replace. For this purpose, the woody core material furnished by the farmer could not carry a delivered price of more than £340/MT (US\$17.00/MT) although, at the higher price, it could be considered as possibly economical for the manufacture of particleboard and/or newsprint at the project pulp mill.

5. The Potential Market for Kenaf Paper Pulp from a Mekong Basin Project Mill

5.1. Introduction

In making this Study, it was found that complete up-to-date statistical information was lacking on the production, importation, and consumption of the various grades of paper within the Mekong riparian countries. Based upon the data available, an estimate has been made of the possible market within this area for the products of a kenaf paper pulp mill that might be built by 1980.

5.2. Capabilities of the Existing Pulp and Paper Industry of the Riparian Countries

An analysis of the information available shows that there has been no existing paper manufacturing industry in Laos and that the small mill at Chhlong in Cambodia was shut down in 1971.

The paper mills in South Viet-Nam were reported as having a capacity of 50,000 tpy. and it was expected that pulp production would reach 15,000 tpy. by 1974.

Thailand has a very active paper manufacturing industry of about 32 mills, based mostly upon imported pulps and waste paper from various sources. The data available indicate existing mills have a maximum total productive capacity of about 40,000 tpy. of pulp (bamboo, bagasse, grasses, and straw). With about 91,000 tpy. of imported pulp and approximately 200,000 tpy. of waste paper, this furnish has been estimated as the requirements for the paper and paperboard that could be produced in Thailand in existing mills under optimum operating and favorable market conditions.

Therefore, it appears that the Mekong riparian countries have a pulp supply of only 55,000 tpy. for a total paper and paperboard manufacturing capacity of about 380,000 tpy. at the present time. It would appear that the local market for pulp in the riparian countries would approximate 100,000 tpy. at full operating rates of the existing mills.

5.3. Importation, Production and Consumption of Pulp, Paper, and Paperboard by the Mekong Basin Countries

A number of reports giving statistical data on these aspects of pulp and paper have been reviewed. In general, it can be said that total per capita paper and paperboard consumption and its growth in the entire area of the Mekong Basin countries has been quite low, as shown by data reported for the period of 1960-1974 as follows:

<u>Area and Country</u>	<u>Consumption of Paper and Paperboard</u> <u>(Kg./Year/Capita)</u>			
	<u>1960</u>	<u>1970</u>	<u>1974</u>	
<u>North America</u>				
Canada	127	169	196	(Least)
United States	196	252	279	(Highest)
<u>Europe</u>				
Albania	8	5	5	(Least)
Sweden	120	191	220	(Highest)
<u>Latin America</u>				
Haiti	1.4	0.5	0.6	(Least)
Costa Rica	7	67	63	(Highest)
<u>Africa</u>				
Burundi	-	0.2	0.03	(Least)
South Africa	27	42	50	(Highest)
<u>Asia and Oceania</u>				
Afghanistan	0.2	0.1	0.1	(Least)
New Zealand	80	114	146	(Highest)
Cambodia	1.3	0.8	0.3	
Laos	1.8	0.9	0.9	
Thailand	2.3	7.3	6	
South Viet-Nam	2.3	3.6	5	

These data indicate that any improvement in the industrial production level and the standard of living and increases in population would apply an upward pressure on these low levels of consumption of paper and paperboard within the Mekong Basin countries.

5.4. Estimates of Future Markets for Kenaf Paper Pulp in the Mekong Basin Countries

The survey does not indicate that Laos or Cambodia would be markets for kenaf paper pulp in the near future, although this Study shows both these countries have potential sites and raw material supplies for the project mill.

In the case of South Viet-Nam, data indicate that, by 1980, that country might have a requirement of 15,000 to 20,000 tpy. of kenaf pulp.

Thailand would have a much higher requirement for pulp than the other countries. In addition, there will eventually be a need to replace the small pulp mills in Thailand lacking recovery systems with a large modern pulp mill with chemical recovery, generation of bleaching chemicals, and effluent treatment facilities. Later on, as consumption increases, this pulp mill would shift over to the manufacture of paper from its own pulp, and the mills to which it formerly sold pulp would obtain their supplies elsewhere or would convert to grades requiring only waste paper.

In this Study, the potential market in 1975 for the Mekong Basin countries for the pulp and paper and paperboard products that could have been made out of kenaf has been estimated to be equivalent to 96,500 tpy. of kenaf pulp of all types. The soda or sulfate pulp equivalents were found to be 57,000 tpy. of bleached whole stalk pulp, 23,000 tpy. of bleached bast ribbon pulp, and 16,500 tpy. of unbleached bast ribbon pulp.

The growth rate of apparent consumption of basic paper and paperboard grades in Thailand was 4.5 percent compounded annually for the period from 1969 through 1974. Based upon a lower and more conservative estimate of growth rate of consumption of 3.5 percent annually for the riparian countries, it was estimated that total pulp equivalent requirements would reach 114,600 tpy. by 1980 and 136,100 tpy. by 1985. This would enable planning for expansion or new pulp capacity beyond the present project mill by the early 1980's and even sooner if newsprint from kenaf is shown to be feasible.

Under the present situation, it is estimated that the 70,000 tpy. of kenaf pulp manufactured by the project pulp mill would all find a market by 1980, which is the soonest such a project could begin production even if final planning and building started now. However, if a large integrated pulp/paper mill based on bagasse and bamboo, as has been planned, were to be implemented before or shortly after the kenaf pulp mill, a strong competitive constraint for the kenaf pulp mill would develop. Without export markets for the kenaf pulp, present viability based only on potential local markets would be greatly diminished and planning and building of the kenaf pulp project might be delayed another 5 to 10 years until a level of consumption requiring the additional productive capacity for pulp is reached.

For this reason, in this Study it has been concluded that the project pulp mill must be equipped with a pulp drying machine of the fourdrinier type with can-type driers, so that production can be shifted from pulp to paper as soon as markets develop for the latter.

This reasoning on the adverse competitive possibilities in Thailand for the kenaf pulp mill is also based on the Consultants' judgement that the high growth rate in consumption of paper and paper board of 7 to 10 percent compounded annually, as estimated in earlier reports, will not be attained in the Mekong Basin countries for the period 1975-1985. These high estimates of consumption given in various studies were based on a period of rapid expansion of the paper industry in Thailand in the 1960-1970 period. Actually, the total consumption of paper and paperboard in Thailand increased only 4.5 percent in the period from 1969 to 1974 and, therefore, a growth in consumption of such products of more than 3.5 percent compounded annually for all of the riparian countries can not be expected for the foreseeable future.

5.5. The Possibilities of Export Markets for Kenaf Paper Pulps as Related to Technical Qualities and Future World Demand for Paper and Paperboard

From the technical standpoint, there are no reasons why kenaf bast ribbon pulp could not be sold on the export market to mills in East Asia as a substitute for softwood sulfate pulp. From the economic standpoint at the present time, however, kenaf bast ribbon pulp would have quite a cost disadvantage. The cost of fibrous raw material in the form of bast ribbon in Thailand is much higher for a ton of pulp than the cost of softwood chips in the developed pulp producing countries. Therefore, at present pulp prices, for kenaf bast ribbon pulp to be competitive, it would be necessary to develop a dry process to separate the bast ribbon from the woody core material of field dried whole stalk kenaf at

the pulp mill, or both the core and bast ribbon material would have to be delivered to the mill. This would make the woody core material, available for fuel, at the pulp mill or for the manufacture of mechanical pulp for newsprint and thereby reduce the cost of the bast ribbon below that projected in this Study's agro-economic sections.

A long range shortage of softwood pulp on the world export market is also expected to develop as consumption increases in the presently producing countries; finished paper products, rather than pulp, will then be manufactured and consumed locally or exported. The cost of softwood pulpwood in developed countries will also probably increase at a greater rate than the cost of kenaf bast ribbon in the Mekong Basin area. It also will be more than 20 years before sufficient softwood plantations producing relatively low cost fibrous raw material for pulp can be developed in the tropical areas. It is believed that the premium price for softwood sulfate pulp over hardwood pulp will increase greatly. These factors tending to raise the cost of softwood for pulp are seen as favorable for reducing the existing gap between the cost of kenaf bast ribbon for pulp and softwood chips. Some of the major pulp sales companies serving the Asian market agree with this analysis of the situation.

A somewhat different situation is anticipated for hardwood market sulfate pulp. Pulp mills planned for the South Pacific-Asia area to use mixed tropical hardwoods and, later on, low cost plantation hardwoods, will have the advantage of "economy of size" as well as very low wood costs. Kenaf whole stalk pulp would not only have to compete with the hardwood pulp but with the bagasse pulp that could be manufactured for export by a number of countries where this lower cost raw material is available.

From this Study, it does not appear that export markets for the projected mill would be necessary as long as competition does not arise in the beginning years from a new bagasse and bamboo pulp mill in Thailand. Consideration of the predicted increase in consumption of pulp and paper products in Far East Asia, however, leads to the conclusion that the products of this mill could be sold outside the Mekong riparian countries when necessary. One of the major studies reviewed has projected a growth rate of 5.2 percent and an increase in paper and paperboard demand in Asia of 11.3 million tpy. by 1980 and 56 million tpy. by the year 2000. To produce this amount of pulp would require the building of 162 mills the size of the Mekong project mill by 1980 and 800 such units by the year 2000.

The Consultants do not believe that the projected consumption levels will be reached due to a shortage of productive facilities. The expected demand in that area of the world, however, will most likely provide markets for all the kenaf whole stalk or bast ribbon pulps that would be produced in the Mekong Basin, assuming costs for fibrous raw materials would make these pulps competitive with wood pulps.

6. Choice of Products, Capacity and Location for a Kenaf Paper Pulp Mill in the Mekong Basin

6.1. Grades and Types of Kenaf Pulps to be Produced in the Model Mill

The various grades and types of pulps that could be produced commercially from kenaf bast ribbon, whole stalk, or woody core material have been discussed. The best quality pulps that could be made from kenaf with conventional pulping, bleaching, and spent liquor recovery systems would be the unbleached and bleached bast ribbon and whole stalk soda or sulfate grades. These would be comparable in paper making properties to softwood sulfate and hardwood sulfate pulps respectively. The kenaf woody core material alone is not considered suitable for production of full chemical pulps.

Kenaf has great versatility as a fibrous raw material for paper-making because pulps the equivalent of softwood long fibered pulp or hardwood short fibered pulp can be produced from it as required for the market using the same mill equipment and processes for both types. This is a very favorable characteristic of the nonwood plants which have a high bast fiber content.

6.2. Model Pulp Mill Capacity

The "economy of scale or of size" is a very important investment and cost factor in the manufacturing of pulp. The most recent single-line equipment mills have been built to produce 700 to 1000 tpd. of hardwood and/or softwood pulps. Nonwood plant fiber pulp mills using bagasse have been planned for up to 500 tpd. output.

Such mills of maximum capabilities have lower operating costs, are more efficient, and have lower capital investment per ton of capacity than smaller mills.

In designing this project, it has been considered that a Mekong Basin bleached market pulp mill producing less than 200 ADMT/day would not be economically viable when using kenaf. The correctness of this estimate is indicated by the financial projections for this size mill as discussed in Chapter IX.

The following data on estimated investment requirements for complete kenaf bleached pulp mills built today on a "turn key" basis clearly show the effect of "economy of size."

Rated Daily Productive Capacity of Pulp Mill (ADMT/Day)	Turn-Key Kenaf Pulp Mill Project Total Investment Requirements (US\$/ADMT/Day)
100	550,000
200	425,000
400	350,000
700	310,000

It is quite obvious from these data that the smaller the mill, the greater the burden of debt repayment and interest that must be covered by the sales price of each unit of product. As brought out elsewhere in this report, it is actually only under especially favorable circumstances of fuel, fibrous raw material, and labor costs that a pulp mill project of 200 ADMT/day size for the Mekong Basin shows economic viability when producing kenaf whole stalk bleached pulp and selling it at the present prices paid for imported hardwood bleached sulfate pulp in Thailand.

6.3. Locating Pulp Mill Sites in the Mekong Basin

Based on information on potential kenaf supplies and available infrastructure, the most logical choice for the proposed pulp mill would be in the Mekong Basin within Northeast Thailand.

6.3.1. Potential Mill Locations Based on Water Availability

Although the mill designed for this project would include facilities for air and stream pollution control to meet the standards set by the Thai Government regulatory authorities, one of the primary requisites for a pulp mill site is that it be located near a large river with appreciable flow even in the dry season. This river not only furnishes water to the mill when water from wells can not be produced at low cost and in sufficient quantity, but is necessary for disposal of the mill's effluent. This is after the effluent has been treated to remove most of the fiber and oxygen-consuming materials in it, which represent only a small percentage of the fibrous materials processed, and the spent pulping liquor recycled to the recovery system.

Based on stream flow data from the Lower Mekong Hydrologic Yearbook, consideration was given to 22 possible sites on the Mekong, Stung Sanke, Nam Pong, Nam Chi, Nam Takong, Nam Mun, Se Bang Fai, Se Bang Hieng, Dak Bla, Ka Krong, Se Kong, Se San, and Sre Pok rivers in the Mekong Basin.

Although having sufficient water flow in the rivers, most of these locations were discarded because they lacked too many of the other major requirements of infrastructure for a pulp mill site.

6.3.2. Potential Mill Locations Based on Technical, Sociological, Economic, and Ecological Requirements

Location of a pulp mill requires a nearby or, at least, readily available supply of fibrous raw material, a basic area established in infrastructure, communication and transportation facilities, adequate water supply and effluent disposal means, accessibility to chemicals and fuel, a nearby electric grid for start-up and standby power, a pool of skilled and unskilled labor, and the schools, hospitals, and business facilities provided by a nearby city. These are in addition to the normal requirements for suitable land for the plant and mill community nearby.

Based upon these criteria, it has been determined that there are six potential areas for kenaf pulp mill locations in the Mekong Basin that would possibly serve the purposes of this Study. Only two of these areas, in Northeast Thailand, have been considered to be of primary importance and they were investigated during the field survey. However, all of the primary and secondary locations are discussed in the main text of this report for their possible advantages and disadvantages in relation to this project, based on the limited information available to the Consultants on the secondary site areas.

Site I of the two primary potential areas of approximately equal suitability is located at the Ubolratana Resettlement Area of the Province of Khon Kaen. At least two potential sites are about 35 to 40 km. north of the town of Khon Kaen on the Nam Pong River between the Ubolratana Dam and the Friendship Highway running parallel to the railroad.

The other primary location (Site II) found to be suitable is near Ubon Ratchathani in the Province of Ubon Ratchathani. Several excellent sites are along the Nam Mun River below the city. This location not only benefits from the large flow of water in the river but also appears to be within economic transportation distance of potential kenaf production areas in neighboring Laos and Cambodia.

The secondary potential mill sites that have been considered, based on the limited information available, are:

Site III - Stung Treng, Province Stung Treng, Cambodia,
on the Mekong River.

- Site IV - Phnom Penh in the Province of Kandal, Cambodia,
on the Bassac or Mekong Rivers.
- Site V - Battambang in the Province of Battambang, Cambodia,
on the Stung Sanke River.
- Site VI - Drayling in Darlac Province, Viet-Nam,
on the Ka Krong River.

These locations for possible mill sites appear to be less favorable than the two primary sites.

7. Kenaf Raw Material Requirements and Supplies

The bleached pulp yield from whole stalk kenaf raw material being estimated at 35 percent, a 70,000 ADMT/year whole stalk kenaf pulp mill will require 206,000 FDMT/year of whole stalks or, assuming a 12½ percent moisture content of the FD stalks, 180,000 ODMT/year. At an estimated FD whole stalk yield range of 7,500 to 9,375 kg./ha. (1,200 to 1,500 kg./rai) for H. sabdariffa, this is equivalent to a planting area requirement of from 22,000 to 27,500 ha. (137,500 to 172,000 rai). At an estimated FD whole stalk yield range of 15,000 to 20,000 kg./ha. (2,400 to 3,200 kg./rai) for H. cannabinus, it would require a planting area of from 10,300 to 13,750 ha. (64,500 to 86,000 rai).

The bleached pulp yield from kenaf bast ribbon raw material being estimated at 45 percent, a 70,000 ADMT/year long fiber pulp mill will require 160,000 FDMT/year of ribbon or, assuming a 12½ percent moisture content of the FD ribbon, 140,000 ODMT/year. At an estimated ribbon yield of 24 percent of the whole stalk, equivalent to an estimated FD ribbon yield range of 1,800 to 2,250 kg./ha. (290 to 360 kg./rai) for H. sabdariffa, this is equivalent to a planting area requirement of from 71,000 to 89,000 ha. (444,000 to 555,500 rai). At an estimated FD ribbon yield range of 3,600 to 4,800 kg./ha. (580 to 770 kg./rai) for H. cannabinus, it would require a planting area of from 33,500 to 44,500 ha. (209,500 to 278,000 rai).

Under Lower Mekong Basin conditions, it is anticipated that kenaf will continue to be produced by small holders, as presently in Northeast Thailand, preferably supported by pulp mill or cooperative organized central (nucleus) farms servicing neighboring production areas. This Study assumes that, in Northeast Thailand, the pulp mill(s) will purchase only up to 25 percent of the kenaf crop in any one season in order not to disrupt the traditional retted fiber sales to the local bag factories and the exporters; no such kenaf raw material purchase limitations are assumed to apply to Laos, Cambodia and Viet-Nam.

CHAPTER II - HISTORY OF THE KENAF AND ALLIED FIBER INDUSTRY IN THE RIPARIAN COUNTRIES

1. Introduction

Kenaf is the common popular name of two closely related jute substitute fiber plant species, namely Hibiscus cannabinus (or Western Hemisphere kenaf) and Hibiscus sabdariffa (or South Asian kenaf, also known as Thai kenaf, mesta and rosella), where H. cannabinus is grown mostly in Africa and Latin America and is the faster maturing and higher yielding species but requires somewhat better soil and climatic conditions, and H. sabdariffa is cultivated principally in India, Bangladesh, Thailand and Indonesia and matures more slowly and produces lower yields but is more drought and disease resistant. Both species are photo-sensitive but a number of varieties with different photoperiod response have been selected for H. cannabinus.

2. Cambodia

Kenaf was introduced into Cambodia in the mid-1950's and, by 1971, was grown by small holders in seven central and western provinces of the country where it has largely replaced jute. No overall fiber production statistics are available but it is estimated that it never exceeded 4,000 tons annually all of which was consumed by the bag factory at Battambang. Preliminary research trials showed that two kenaf crops can be grown per year and that, with proper management, retted fiber yields of 2.5 tons per hectare and more can be obtained.

3. Laos

Due to the lack of a local market, no attempts at the development of a kenaf industry have been made in Laos in the past. An effort to organize the production of polompom, a native bast fiber plant, met with little success and was soon abandoned.

4. Viet-Nam

Both kenaf and jute have long been grown in Viet-Nam for village and domestic cottage industry consumption.

Intensive kenaf research and fiber production efforts were started in 1958 and, by 1961, the crop had been introduced into 15 provinces. Output reached its maximum with 9,000 tons in that year but then declined due to war related causes, but small scale production continues to this day, particularly in Tay Ninh, Darlac and Kontum Provinces. There is no question that both H. sabdariffa and H. cannabinus can readily be grown in Viet-Nam and that retted fiber yields in the 2.5 tons per hectare range can be realized.

Similar jute research and fiber production promotion resulted in a maximum output of some 2,500 tons in 1960 in four provinces in the Delta and demonstrated that retted fiber yields of 2,000 to 2,350 kg. per hectare could be achieved.

5. Thailand

Commercial kenaf fiber production in Northeast Thailand, one of the lowest income areas of the country, rapidly increased after its initial introduction in 1950. For the last ten years, retted fiber production has fluctuated generally between 350,000 and 500,000 tons annually, with an average of 440,000 tons but with peak outputs of more than 620,000 tons in 1966 and 1973. During that same period, the crop was planted on between 320,000 ha. and 480,000 ha. (2 and 3 million rai) per year, with an average of 384,000 ha. (2.4 million rai) annually but maxima of 528,000 ha. and 544,000 ha. (3.3 and 3.4 million rai) in 1966 and 1973 respectively. For 1975, the planting area is estimated at just short of 320,000 ha. (2 million rai) and retted fiber yield is projected in the 300,000 tons range. The statistics show wide fluctuations in annual outputs (e.g. 184,000 tons in 1968 and 625,000 tons in 1973) and that as a result of wide fluctuations in the farm level price of the fiber which, in turn, is largely determined by the size and price level of the jute crops in India and Bangladesh. More recently, tapioca has replaced kenaf to a substantial degree in the Northeast in view of its ease of production and the very attractive prices offered for the crop combined with a decline in kenaf fiber yields from 1,250 to 1,150 kg./ha. (200 to 184 kg./rai) and less as a result of lack of research and of improved seed, and a general decline in soil fertility in the absence of conservation measures.

Domestic kenaf fiber demand by the twelve local bag mills and for village consumption is estimated at about 230,000 tons per year. Exports have varied from 220,000 to 320,000 tons annually between 1965 and 1974 but are forecast at an average of only 175,000 tons yearly over the next ten-year period in view of the general decline in the international jute and kenaf market due to competition from the man-made fibers. The combined local and export demand for retted kenaf fiber would then amount to, say, 400,000 tons per year which, at an average yield of 1,150 kg./ha. (184 kg./rai), could be produced on some 350,000 ha. (2.2 million rai).

A limited amount of jute fiber is also produced in Northeast Thailand and outputs of as much as 20,000 tons annually have been achieved in recent years. Although its soil and climatic requirements restrict successful jute production principally to the northern and eastern sectors of the Northeast, i.e. to a band adjacent to the Mekong River, it is estimated that, with intensive promotion and an assured and attractive market, a 100,000 tons per year jute fiber output could well be achieved.

CHAPTER III - KENAF AGRONOMY AND FIBER PRODUCTION

This chapter provides an overview of the general agronomy of kenaf for textile fiber production upon which any future kenaf for paper pulp production will have to be based.

For H. sabdariffa, the standard practices in Thailand are cited where kenaf is generally grown on low fertility sandy upland soils and with a minimum of mechanization. The land is plowed and raked with animal drawn wooden implements and the seed is planted by hand after the start of the rainy season in May and June, still largely by broadcasting rather than in rows as recommended for higher yields and lower costs. After 30 days, the crop is weeded and the seedlings thinned to a distance of 7 to 10 cm. between plants; a second weeding should be done 30 days later. Fertilizer is used only rarely. The species is highly disease resistant although some inroads have been made by collar rot and the development of immune varieties is essential. Preferably, the stalks should be harvested when they start flowering - about mid-October in Northeast Thailand - but in practice harvesting is done from as early as the end of August to as late as March, with an interval for rice harvesting in December and January. The stalks are either cut at ground level with a bushknife or pulled out of the ground and then shocked in upright bundles for field drying prior to transport to the retting facility.

H. cannabinus, with its shorter growing cycle and higher yield, is somewhat less drought resistant than its South Asian cousin, requires somewhat better quality soils, and is susceptible to rootknot nematodes so that it should not be grown on light sandy soils. Land preparation in the riparian countries would probably duplicate that for H. sabdariffa, although some mechanization would be desirable on the heavier soils suitable for the crop. It should also be planted in rows and adequately fertilized. Seed varieties with different photoperiod response are available to permit extensive staggering of the planting (and harvesting) dates. Due to rapid seedling growth and the mostly palmate leaves of the species, H. cannabinus plantings need not be weeded or thinned since their leaf "carpet" shades out both the weeds and the less vigorous slower growing seedlings. Again, harvesting should be done at the flowering stage and, as with South Asian kenaf, the plants are mostly cut by bushknife; however, almost all Western Hemisphere kenaf is ribboned, i.e. the bast is stripped off the stalk by hand or by machine, and this must be done while the stalk is still fresh:

In Northeast Thailand and in Southeast Asia in general, the whole kenaf stalks are submerged in water for retting; after the decomposition of the vegetable matter in the bast, the fiber is stripped from the stalk by hand, washed, dried and field baled, and then sold to the local merchant, a baling plant, or a bag mill. In the Western Hemisphere kenaf growing areas, on the other hand, the stalks are almost always ribboned before retting, principally because this reduces both labor and water requirements very substantially.

All kenaf and jute in Southeast Asia is produced by small holders. This Study suggests that the small holders could greatly benefit from the organization of central or nucleus farms which would assist the growers in their areas by providing improved seed, fertilizer, agricultural equipment and ribboning machine services, and centralized retting facilities, all on credit repayable at harvest time, as well as extension services and marketing assistance. Such nucleus farms could be either Government or cooperative or, eventually, pulp mill administered and could, in the latter case, form part of a commercial plantation type operation designed to produce a minimum raw material supply for the mill and, simultaneously, to serve as demonstration and extension center.

CHAPTER IV - POTENTIAL KENAF PRODUCTION AREAS IN THE LOWER MEKONG BASIN

From the point of view of soil quality, ample areas suitable for kenaf for paper pulp production exist within the Mekong watershed in all four riparian countries, including the traditional kenaf growing area in Northeast Thailand; the Vientiane Plain and the Provinces of Khammouane, Savannakhet, Sedone, Champassac and Sithandone in Laos; most of Cambodia with the exception of the mountainous area facing the Gulf of Thailand, the Tonle Sap flood plain, and part of the hill country in the east; and substantial portions of the Provinces of Darlac, Pleiku and Kontum in Viet-Nam.

CHAPTER V - KENAF PRODUCTION FOR PAPER PULP

1. Kenaf Stalk Composition

Extensive tests on the composition of H. cannabinus in the United States showed an average stalk fraction ratio of 60 percent core and 40 percent bast ribbon material. No similar tests having been carried out for H. sabdariffa, this Study assumes that its stalk composition is the same. Detailed stalk composition tests on both species of kenaf grown specifically for paper pulp manufacture under Lower Mekong Basin conditions are essential.

2. Kenaf Production Agronomics

2.1. to 2.7. "Land Preparation, Planting, Cultural Operations, and Seed Production"

Good land preparation is essential to assure uniform kenaf seed germination. For H. sabdariffa, additional development work on improved seed varieties is required; for H. cannabinus, the standard Cuban, Guatemalan and Everglades varieties should be used.

The start of planting should coincide with the start of the rainy season and planting of the photo-sensitive varieties should be completed not later than the second half of June; however, the late maturing varieties (e.g. Guatemala 4 and 45) permit planting on a much more extended schedule. Row-planting should be strongly encouraged, since it results in higher yields and lower labor requirements, and it should preferably be done either with the help of a multi-row seed rake or by tractor drawn seed drills on larger operations. Since H. sabdariffa has to be weeded and thinned, it should be planted at an inter-row distance of 30 cm; the row spacing for H. cannabinus, on the other hand, will be 17 to 20 cm.. The seeding rates should be 12.5 kg. and 25 kg./ha. (2 and 4 kg./rai) respectively.

H. sabdariffa is fertilized only rarely in Northeast Thailand and, in view of the maximum 25 percent yield increase resulting from fertilizer application and of its present cost, such application apparently produces a positive financial return to the grower only if the farm gate price of Mixed Grade retted kenaf fiber exceeds \$3.30/kg. (\$0.165/kg.) which has seldom been the case. On the other hand, much greater yield increases have been achieved through fertilization in the H. sabdariffa research program in Viet-Nam. H. cannabinus always responds strongly to fertilizer application, particularly nitrogen, and this applies also under Lower Mekong Basin conditions as already confirmed by the research programs in Cambodia and Viet-Nam. Further research is required into this aspect of the kenaf for paper pulp development program.

H. sabdariffa should be weeded twice, 30 and 60 days after planting, and the seedlings thinned to 7 to 10 cm. between plants immediately after the first weeding. Due to the shading effect of its faster growing seedlings, these operations are not required for the H. cannabinus species.

Although both South Asian and Western Hemisphere kenaf are exceptionally pest and disease resistant, these do of course occur; standard control measures are itemized in this Study. Special attention is drawn to the rootknot nematode susceptibility of H. cannabinus on light sandy soils.

For a successful kenaf for paper pulp production program, the large scale production of improved seed is of much importance, a matter so far sadly neglected. It is estimated that an annual improved H. sabdariffa seed planting area of from 900 to 3,000 ha. (5,600 to 19,000 rai) and an H. cannabinus seed area of from 500 to 1,700 ha. (3,100 to 10,000 rai) would be required, to satisfy the raw material requirements of the whole stalk kenaf and the kenaf bast ribbon pulp mills respectively.

2.8. Harvesting

In order to obtain maximum yields, H. sabdariffa should not be harvested before mid-October in the Lower Mekong Basin area; the harvest of the faster maturing H. cannabinus species can start as early as mid-August.

For whole stalk production, the kenaf should be cut close to ground level by bushknife in the traditional manner; thereafter, some 30 cm. of the tip ends should be cut off and the plants shocked vertically for field drying. The operation can be mechanized in large scale operations through the use of a cutter bar or a high crop harvester.

For chopped stalk production, the small holder would then simply cut the dry stalks into chips of the desired length or he could deliver his stalks to a central chopping plant. The operation could again be mechanized through the use of standard forage harvesters or similar equipment, but much work remains to be done to properly adapt such equipment to kenaf for paper pulp production.

For bast ribbon production, the long fiber bearing bast is stripped from the stalk either by hand or by machine, as has been standard practice in retted kenaf fiber production for many years, particularly in Africa and Latin America. Various simple aids have been developed to facilitate manual bast stripping or ribboning and efficient ribboning machines are commercially available.

3. Whole Stalk Kenaf Raw Material

3.1. Whole Stalk Kenaf Raw Material Requirements

As discussed previously, a 70,000 ADMT/year whole stalk bleached kenaf pulp mill will require 206,000 FDMT/year of stalks and this Study arbitrarily assumes that such a mill will be established at the potential Site I at Nam Phong near Khon Kaen in Northeast Thailand and uses that mill as an example for other whole stalk kenaf pulp mills which could be established elsewhere in the Basin area.

3.2. Kenaf Stalk Yield Per Unit Area

The basic aspects of kenaf for paper pulp project development have, so far, been only fragmentarily researched anywhere outside the United States. Nevertheless, it is considered that the results obtained in limited tests in Northeast Thailand indicated that a yield of at least 7,500 kg./ha. (1,200 kg./rai) of field dry H. sabdariffa stalks can be obtained in that region and that it might increase to some 9,375 kg./ha. (1,500 kg./rai) under somewhat more favorable soil conditions. Similarly, using the U.S.A. research results as a basis, it is conservatively estimated that H. cannabinus field dry whole stalk yields in the Basin area will range from 15,000 to 20,000 kg./ha. (2,400 to 3,200 kg./rai).

3.3. Kenaf Production Areas and Whole Stalk Supplies Within Economic Distance of Mill Site I

It is assumed that whole kenaf stalks can be trucked economically to the mill site from a distance of up to 160 km. A listing of all kenaf producing districts within that distance from Mill Site I shows a total average annual kenaf planting area, during the 1970 to 1974 period, of some 198,000 ha. (1,240,000 rai). At a stalk yield of 7,500 kg./ha. (1,200 kg./rai) and a total stalk consumption of 206,000 tons, a kenaf planting area of about 27,500 ha. (172,000 rai) per year will be required; at the same time, only 25 percent of the available kenaf crop is to be purchased in the Northeast by the mill so as not to disrupt the established kenaf fiber trade. Hence, a total annual kenaf planting area of some 110,000 ha. (688,000 rai) is necessary to cover the mill's whole stalk raw material requirements. The listing and supporting tables and maps show that these requirements could be purchased within a maximum transportation lead distance of 120 km.

3.4. Kenaf Stalk Procurement

One system of stalk procurement could be through a pulp mill operated organization. On the assumption that the small holder can conveniently transport his stalks by bullock cart over a maximum distance of 15 km., this would require the establishment of 4 collection centers and 20 satellite purchasing depots within the supply area where the stalks brought in by the farmers would be weighed, paid for, and stacked pending dispatch to the nearest collection center or the pulp mill.

A second and preferable stalk procurement system would be to contract with the existing kenaf baling plants and traders. It is submitted that this approach would not only relieve the pulp mill of all organizational problems of raw material purchasing and would be more economical, but that it would also assure the cooperation of the established kenaf trade rather than arouse its opposition through competition for the available kenaf raw material. In addition, this procedure would open up the entire Northeast as a raw material supply area since the more distant kenaf balers and traders would be willing to absorb the greater stalk transportation costs.

Finally, it is anticipated that a portion of the mill's kenaf stalk requirements could be purchased through local cooperatives, as for example the Ubolratana Resettlement Area Cooperative which could potentially furnish up to one-third of the needs of a mill at Site I, and it is hoped that the participation of cooperatives in supplying the raw material requirements of the mill(s) will rapidly increase.

Loose stalks being too bulky to be transported economically by truck, they must at least be field bundled by the growers; much as they are used to doing with retted fiber. The stalks could then be further compressed in the regular kenaf fiber baling presses. It is reported that bulk densities of 100 to 120 kg./cu.m. and 300 to 400 kg./cu.m. respectively are achieved by these two methods without crushing the stalks.

The stalk field bundles would be transported by the growers to the nearest collection center, depot or road head with their own bullock carts. Stalk transport between the road head, the depots/collection centers and the mill would be by truck.

4. Chopped Stalk Kenaf Raw Material

4.1. Chopped Stalk Field Handling

As previously indicated, if chopped kenaf stalk material is to be supplied to the mill, the stalks could either be chopped by the farmers by hand or harvester-choppers could be employed. In either case, it is essential that, during subsequent storage, the moisture content of the chips does not exceed 35 percent at the most. When the kenaf is harvested after about mid-December in the Lower Mekong Basin, these moisture limitations would not be exceeded since the rainy season is then well past; if necessary, the stalks could be shocked before chopping or the chopped material spread on the ground to achieve further drying. However, harvesting prior to, say, mid-November definitely presents a chip drying problem; it could be overcome by harvesting and shocking the stalks prior to chipping, either by hand, by mobile field choppers or by stationary choppers, say at the baling plants, or by artificial drying.

4.2./4.3. Chopped Stalk Baling and Transport

Since loose stalk chips have a bulk density of only some 72 kg./cu.m., they must be baled for economic long distance transport and the standard kenaf fiber baling presses should prove adequate for the purpose and could produce bales with a bulk density of at least 427 kg./cu.m. Whereas the standard 30 cu.m. body of both the local 6-ton and 10-ton trucks would hold only a little more than 3 tons of stalk chips, close to 13 tons of stalk bales could then be loaded into that same body by volume.

5. Kenaf Bast Ribbon Raw Material

5.1. Kenaf Ribbon Raw Material Requirements

As already discussed, a 70,000 ADMT/year bast ribbon bleached kenaf pulp mill will require 160,000 FDMT/year of ribbon and this Study again arbitrarily assumes that such a mill will be established at the potential Site II near Ubon Ratchathani in Northeast Thailand and uses that mill as an example for other long fiber kenaf pulp mills which could be established elsewhere in the Basin area.

5.2. Kenaf Ribbon Yield Per Unit Area

Based upon the Consultants' long-term experience with H. cannabinus ribbon production for subsequent conversion into retted fiber, ribbon yield ranges for Western Hemisphere kenaf are set at 3,600 to 4,800 kg./ha. (580 to 770 kg./rai). They are estimated therefrom at 1,800 to 2,250 kg./ha. (290 to 360 kg./rai) for H. sabdariffa, an estimate which is confirmed by conversion into known retted South Asian kenaf fiber yields in Northeast Thailand.

5.3. Kenaf Ribbon Supply Area Parameters and Supplies

Based on the previous assumption that whole kenaf stalks could be trucked economically over a maximum distance of 160 km. and in view of the greater pulp yield and greater bulk density of kenaf ribbon, the maximum economic transportation distance for the latter is assumed to be 270 km. by road or 200 km. in a straight line. A circle with that radius drawn around Mill Site II covers some 50 percent of the traditional kenaf production area in the Northeast as well as most of the potentially suitable kenaf areas in Laos and the Northern tier of provinces in Cambodia.

If only H. sabdariffa ribbon supplies are assumed and since, in the Northeast, only 25 percent of the available kenaf crop is to be purchased by the mill, a total planting area of 355,500 ha. (2,222,000 rai) would be required to satisfy the raw material requirements of the mill or almost twice the average 1967 to 1974 annual planting area in the Northeast within the 200 km. straight line parameter from Mill Site II; the shortfall could be made up by yield increases as a result of supplies of improved seed, a planting area increase as a result of pulp mill offered incentives, a production increase in the seven Resettlement Areas within easy reach of the mill site, from kenaf production in the neighboring provinces of Laos and Cambodia, or from kenaf baler and trader supplies in the remainder of the Northeast.

For H. cannabinus ribbon, the actual required planting area, would be reduced to 44,500 ha. (278,000 rai) because of its higher yield. It is estimated that 27,200 ha. (170,000 rai) would become available within the 200 km. radius from Mill Site II in the Northeast alone and that the balance of 17,300 ha. (108,200 rai) could readily be secured from the neighboring provinces in Laos and Cambodia.

Obviously, any shortfall in H. cannabinus ribbon could also be made up by H. sabdariffa ribbon and vice versa.

5.4./5.5. Kenaf Ribbon Processing, Drying and Baling

The ribboning of the kenaf stalks would be done in the same manner and with the same equipment as used for many years for kenaf textile fiber production, either manually or by machine.

Since ribboning has to be done while the stalks are still green, the ribbon must be dried after stripping by spreading it on bamboo or other drying lines during the rainy season and on the ground during the dry season. It should then be field baled either by duplicating the standard Northeast Thailand retted fiber drum or in a wooden box in which the ribbon could be manually compressed to a bulk density of about 140 kg./cu.m. The ribbon should then be high density baled to about 576 kg./cu.m. in one of the standard Thai kenaf baling presses for long distance transport and subsequent storage.

5.6. Kenaf Ribbon Procurement

As for whole stalks, there are three basic ribbon procurement alternatives available to the pulp mill - by a mill organization, through the kenaf baling plants and traders, and through cooperatives. It is submitted that, in view of the much larger procurement area involved in ribbon purchases and the requirement for high density baling of the ribbon, it would be even more burdensome for the mill to set up ribbon collection centers and depots than for stalk purchases and that the use of the established kenaf trading channels offers the most practical and economic solution apart from assuring the trade's cooperation rather than its opposition; furthermore, it would open up the entire Northeast as a ribbon supply area rather than only a portion thereof. It is also estimated that the cooperatives operating in the Resettlement Areas of the Department of Public Welfare located in the Southern sector of Northeast Thailand could contribute up to 54,000 FDMT of bast ribbon annually to the overall 160,000 FDMT per year ribbon requirements of a kenaf bast ribbon pulp mill established at Site II.

5.7. Kenaf Ribbon Transport

A 30 cu.m. standard truck body could carry only 4 tons of field baled ribbon but up to 17 tons, by volume, of high density baled ribbon. In practice, 10-ton trucks would probably be used and loaded with 12 to 14 tons of the latter type of ribbon bales.

6. Kenaf Raw Material Availability Projection

6.1. Northeast Thailand

The area planted to kenaf each year in the Northeast largely depends on the fiber price the farmer received the previous year and, over the last decade, has fluctuated from as little as 1.1 million rai to as much as 3.4 million rai (171,000 to 535,000 ha.) annually, but has averaged about 2.4 million rai (384,000 ha.). In the past, a steady farm gate price of at least $\text{฿}2.50/\text{kg.}$ ($\$0.125/\text{kg.}$) of Mixed Grade retted fiber encouraged the Northeast kenaf farmers to increase their plantings. Reasonable Northeast Thailand kenaf demand projections indicate that the above average 2.4 million rai (384,000 ha.) annual planting area would just about meet the requirements of the local mills, the fiber export trade and a 70,000 ADMT/year whole stalk kenaf pulp mill, but that it would fall some 350,000 rai (56,000 ha.) short if a kenaf bast ribbon pulp mill using 100 percent bast ribbon raw material was installed.

Until recently, kenaf was the only major upland crop in the Northeast, although it competed for the available upland planting areas with a variety of other crops, where the kenaf was - and is - normally grown on the poorer soils. Such general upland crop plantings are estimated to have reached some 3,250,000 rai (520,000 ha.) in 1975 but did not, in themselves, adversely affect kenaf production. However, a more serious competitor is tapioca which has made some inroads into kenaf production during the last year or two since it can be grown on the same poor soils as kenaf, is easy to produce and, at prevailing and projected market prices, offers the farmer a greater revenue estimated at some $\text{฿}600/\text{rai}$ ($\$187.50/\text{ha.}$) under Northeast conditions which would be equivalent to the gross revenue generated by a Mixed Grade retted fiber farm gate price of $\text{฿}3.25/\text{kg.}$ ($\$0.1625/\text{kg.}$)

Since this Study assumes that the kenaf pulp mill(s) would offer the farmer a gross revenue of ¥600/rai (\$187.50/ha.) for his whole stalks (without further processing and thus as easy or easier to produce than tapioca) and a 10 percent higher revenue for his kenaf ribbon (requiring about the same amount of work as tapioca production), it is then concluded that (i) the availability of upland crop areas in the Northeast is not a limiting factor of the kenaf stalk or ribbon supply potential; (ii) an adequate price incentive can assure an adequate supply; and (iii) the farm price for field dry kenaf stalks and/or ribbon to be offered by the kenaf pulp mill constitutes such an adequate price incentive.

6.2. Laos

Since the small local market could not support a pulp mill, any kenaf for paper pulp produced in Laos would have to be supplied to mills either in Northeast Thailand or in Northern Cambodia. In view of the absence of Government authorization for the Consultants to visit the potential production areas, it can only be assumed that the competitive position between kenaf and other upland crops in Laos would be similar to that in Northeast Thailand and that the prices to be offered for kenaf stalks and/or ribbon by the projected pulp mills would provide an adequate incentive to the Lao farmers to produce the crop.

6.3. Cambodia

The past positive results of kenaf promotion programs in Cambodia seem to indicate that adequate supplies would become readily available once an assured market exists. This combined with the fact that, from the point of view of soil and climatic conditions, the crop can be grown in large areas of the country, would make it appear that prospects for kenaf for paper pulp production in Cambodia do indeed look favorable.

6.4. Viet-Nam

In Viet-Nam, only the Central Highlands Provinces of Darlac, Pleiku and Kontum are both located within the Mekong watershed and offer suitable soil conditions for kenaf production; the Delta, the only other sector of the country in the Mekong watershed area, consists mostly of poorly drained soils and, in any case, is largely reserved for food crop production. Kenaf has been grown successfully in the Central Highlands in the past and extensive areas suitable for its production do indeed exist in the three Mekong Basin provinces. The same applies to 12 other provinces in Viet-Nam and there is no doubt that ample kenaf raw material supplies would become available once a reliable market in the form of a kenaf pulp mill exists.

7. Pulp Mill Demonstration Farm

It is proposed that the pulp mill should establish one or more nucleus farms to serve as extension services, demonstration and, possibly, credit supply centers to the small holder kenaf producers in their respective areas of coverage. Such Demonstration Farm(s) should be organized along commercial plantation lines and one 240 ha. Farm "Unit" is described in detail, where it is assumed that they would be planted to the higher yielding H. cannabinus species of kenaf.

7.1./7.2. Cultural Operations, Seed Planting and Fertilization

The Demonstration Farm area would be thoroughly cleared and stumped to permit extensive mechanization of all farming operations, including plowing, disking, seeding and fertilizer application. No weeding and thinning should be required for H. cannabinus.

7.3. Harvesting and Processing

Whole Stalk Production: Harvesting should start about the middle of December, after the crop has started to dry out, and should be completed by the end of March. The whole stalks should be cut by a high-crop harvester and then topped and field bundled.

Chopped Stalk Production: The same harvesting period applies as for whole stalks. The stalks should be cut and chopped by a forage harvester and the chips blown into a follow-up trailer.

Bast Ribbon Production: Harvesting and ribboning should be scheduled for the August to December period when the stalks are still green and the ribbon can readily be separated from the woody core. The stalks should be cut and bundled by a high-crop harvester and then passed through ribboning machines for bast stripping. After the ribbon has been dried, it should be field baled.

7.4./7.5. Operating Schedules and Equipment, Facility and Personnel Requirements

Detailed operating schedules for all three types of kenaf raw material have been worked out for the 240 ha. Demonstration Farm Unit and it has been established that each Unit will require three 70 to 80 HP. wheel tractors complete with a full range of tractor implements; a fourth stand-by tractor should be provided for general transportation purposes and as a reserve unit. With regard to stalk harvesting and processing equipment, whole stalk production would require two high-crop harvesters; for chopped stalk production, these two units would be replaced by one pull-type forage harvester (or a sugar cane harvester/chopper); and for bast ribbon production, two high-crop harvesters and six ribboning machines would be required.

Including allowances for farm roads and buildings, each Unit would require some 250 ha. and a prefabricated storage shed should be provided.

Each Unit would be administered by a Farm Manager assisted by two Field Supervisors. Except for tractor operators and helpers, all labor would be employed on a temporary basis as and when needed.

CHAPTER VI - THE HANDLING, STORAGE, RECLAIMING, FIBERIZING, AND WET CLEANING OF KENAF AT THE PULP MILL

1. Introduction

Research on kenaf storage, together with the knowledge of the storage of other nonwood plant fibers for commercial pulp/paper operations, are sufficient for the design of systems for storage of green or field dried kenaf at the pulp mill.

2. The Handling of Green and Field Dried Whole Stalk and Bast Ribbon Kenaf Brought to the Mill in Bulk or Bundled Form

Some green and field dried whole stalk and bast ribbon kenaf in either chopped or bundled form would be hauled directly to the mill from nearby farming areas when transportation of the bulky material would be economical. The flow of this kenaf during the harvest season would be scheduled to be less than the daily requirements of the pulp mill so it would be processed directly into the fiber preparation system.

3. The Handling and Storage of Field Dried Whole Stalk and Bast Ribbon Kenaf Bales at the Pulp Mill

Bales of field dried kenaf from the collecting and baling stations and their satellite storage yards would be hauled to the mill by trucks and either used directly in the fiber preparation system or put into storage.

There are a number of bale storage and handling systems which have been used successfully for bagasse and straw pulp mills. They are described in the main text of this report and are listed as the Celotex Method, the Mechanical System, the Taiwan Method, and the Thessalian Method.

It appears that the heating and fermentation problems which have arisen in the storage of bagasse baled at 50 percent moisture content will not be present for the field dried kenaf which would be stored in bales at approximately 12.5 percent moisture. The handling and storage of baled field dried whole stalk and bast ribbon is judged to be a suitable procedure for maintaining at the pulp mill an inventory of about 25 percent of the annual kenaf requirements.

4. Alternative Systems Considered for Bulk Storage and Handling of Kenaf at the Pulp Mill

It has been determined in the agro-economic sections of this Study that transportation of field dried kenaf in high density bales is the most economical way to get it to the mill. It has also been estimated that, because of the low labor cost in the Mekong project mill kenaf storage yard, bulk handling and storage of the kenaf in either wet or dry form would be more costly than bale storage and would not be required to preserve the papermaking qualities of the raw fiber to a satisfactory degree.

The bulk handling and storage systems which are used for wood chips and agricultural residues such as bagasse could be considered for use on kenaf only in an area of labor shortage and high costs or where the kenaf would be grown on large farms with mechanized harvesting and transporting of the crop to the mill in bulk form.

The bulk storage and handling systems that have been used successfully by the bagasse pulp mills and would be suitable for a kenaf pulp mill are the Ritter Biological Process System, the wet bulk storage system developed at Technica Cubana in Cuba and also used by International Paper Company in Puerto Rico, the Valentine Method, and the Celotex Wet Bulk Storage System. These are described in the main text of this Study.

5. The Handling, Fiberizing and Wet Cleaning of Kenaf in Preparation for the Digester

Kenaf, after fiberizing at the pulp mill, would be handled, wet cleaned, and pulped with the same type of equipment used for bagasse and straw. The baled or loose kenaf, in either whole stalk or bast ribbon form, would be shredded or fiberized with the type of machine which is used to prepare sugar cane for the sugar extraction process.

After mechanical preparation of the kenaf fiber, it would be conveyed to a Hydrapulper where a slurry would be made with recycled water whereby the fiber would be washed to remove soluble sugars, waxes, etc. and dirt, sand and fine parenchyma cells and pith would be loosened from the fiber desired for pulping.

The kenaf slurry would then be pumped through a low gravity centrifugal cleaner to separate and remove heavy and abrasive particles, such as sand and dirt, and then onto a rotating dewatering drum, a drainer conveyor, a vibratory screen, or a fourdrinier type wire drainer.

The dewatered kenaf would then be dropped into a centrifugal hammermill-type apparatus similar to a bagasse depither for removal of fiber fines and pith from the longer fiber and for final separation of residual excess water and loose dirt to prepare the kenaf fiber for feeding to the digester.

Photographs of the equipment and flowsheets of processes that would be used for converting the kenaf raw fiber into finished baled pulp for shipment are found in the main text of this Study.

CHAPTER VII - THE UTILIZATION OF KENAF FOR THE MANUFACTURE OF PAPER PULP IN THE MEKONG BASIN PROJECT MILL

1. Introduction

The techniques of producing paper pulp from other nonwood plant fibers have been judged to be suitable for the manufacture of kenaf pulp. In this chapter, the practical aspects of the manufacture of kenaf pulp in the Mekong project mill are outlined.

2. The Harvesting, Transporting and Storing of Kenaf for the Mekong Basin Project Paper Pulp Mill

The large scale mechanized harvesting and bulk transporting systems used in the sugar cane industry would be expected to be used in countries with high labor costs. The wet or dry bulk storage systems that are used for bagasse would also be used for kenaf under the same situation.

Such systems are not considered to be economical or necessary for the fibrous raw material supply for the kenaf paper pulp mill planned in this Study. In the Mekong Basin, where the kenaf would be field dried and produced as whole stalk or hand stripped bast ribbon by the farmers, it would be hauled by cart to the nearest collection station or baling plant. The kenaf would be pressed into high density bales and stored at the satellite storage yards at the baling stations or hauled by truck directly to the pulp mill for processing or storage in the mill yard.

The woody core material from which the bast ribbon would be stripped could be used for fuel, particleboard, or for certain types of pulp such as mechanical pulp for newsprint or semichemical pulp for corrugating medium. However, for the project as planned, such items are not considered for the mill.

3. The Expected Effects of Storage Conditions on Yield and Quality of Kenaf Paper Pulps in the Mekong Basin Project Mill

The technical reports reviewed have stated yields of pulp ranging from 30 to more than 40 percent for kenaf whole stalk pulp. Bleached pulp yields from as low as 35 percent to as high as 55 percent have been reported for the bast ribbon. In most cases, the higher yield values have been found to be based on the moisture-free weight of the fiber fed to the digester and the moisture-free weight of the bleached pulp produced. While correct as digester yield values in most cases, the high values can be very misleading if considered in predicting the overall yield between the field yield of the green kenaf stalk at

maturity or time of frost kill and the yield of bleached pulp off of the pulp dryer. In the case of some of the reported high yield values, it was obvious that something not mentioned had happened to the kenaf sample before it was cooked and which removed material that would have been removed from the fiber in pulping, thus resulting in a correspondingly lower yield value.

Considering that the USDA has found that about 25 percent of the kenaf stalk dry solids at maturity is water soluble organic matter consisting of gums, sugars, etc., it becomes obvious that the confusion and inconsistencies in yield data reported result from the removal of some of these materials prior to the cooking trials. These losses in solids can result from leaching by the rains during the field drying, during storage when bulk storage systems are used, and as a result of wet cleaning the raw fiber in preparing it for the digester. Such losses are in addition to the mechanical losses of kenaf in harvesting, handling, and storage and the losses of fine fibers in the processing through the pulping and bleaching and papermaking operations before finished pulp in bales is produced for sale.

Taking all these factors into consideration, it appears that, in the projected pulp mill, the average overall yield of kenaf bleached whole stalk pulp will be 35 percent on an oven dry equivalent (moisture-free) basis of the raw material as purchased from the farmer. On the same basis, the finished pulp yield for kenaf bast ribbon has been estimated to be 45 percent.

As for the possibility of detrimental effects of storage and handling the raw fibrous materials on the yield and physical strength properties of the pulps, the system using covered bale storage of the field dried kenaf for the project mill will minimize such effects. Although alternative systems for mechanized harvesting, and bulk handling and storage of kenaf would not be used for this particular project due to their higher cost, they would be equally satisfactory for use on kenaf.

4. The Effect of Wet Cleaning the Kenaf on Pulp Yield and Quality and Mill Operation

Some studies have shown the improvements in pulp physical strength properties and drainage rates which result from wet cleaning the fibrized raw material to remove the sand, dirt, organic acids and other soluble materials and some of the pith, parenchyma cells, and other fibrous debris before cooking the kenaf. In addition, as is the case for commercial operations pulping straw and bagasse, such a wet cleaning step will have many beneficial effects in the subsequent pulp

washing and bleaching steps and the recovery of the spent liquor from the pulp. These benefits accrue with little or no additional loss of papermaking fiber than would occur at other points further on in the process if the wet cleaning had not been done.

5. Pulping and Bleaching Processes and Conditions Suitable for the Manufacture of Paper Pulp from Kenaf in the Mekong Project Mill

Although almost every possible grade and type of pulp has been produced experimentally from kenaf whole stalk, woody core material and bast ribbon, most of them could not be considered to be suitable products for the project mill. Based upon the market for pulp in the Mekong riparian countries, the logical choices for mill products are the unbleached and bleached grades of fully cooked chemical pulps made from kenaf whole stalk or bast ribbon by the soda or sulfate (kraft) processes.

In the project mill as planned, the wet cleaned kenaf would be cooked in a continuous, horizontal tube-type digester, as is used for other nonwood plant fibers, where only a short cooking cycle at high pressure is required for the fiberized material.

Following this, the spent liquor washed out of the kenaf after it is cooked would be returned to the liquor recovery system. The steps in this process are evaporation of the spent liquor followed by burning it in the recovery furnace to remove the organic materials cooked out of the kenaf from the sodium salts that are the basis for the cooking liquor. The solution of sodium salts is then treated (causticized) with reburned lime to convert them into alkali for cooking more kenaf and the lime sludge is recycled and reburned to convert it back to lime for use again in the causticizing process.

For bleaching, any one of the several standard sequences of chemical treatments used on pulps from wood, straw, or bagasse would be satisfactory. For the project mill, the bleaching sequence CEHD (chlorination, alkaline extraction, calcium hypochlorite, and chlorine dioxide) with a final wash with sulfur dioxide as an anti-chlor has been chosen.

For maximum economy and efficiency of operation, the project mill as planned would include electrolytic facilities for producing part of the cooking chemicals and all of the bleaching chemicals required. Lime makeup would be produced from burning limestone in the sludge reburning kiln.

6. The Anticipated Characteristics of Kenaf Pulps in Washing and Screening

The major criticism of kenaf pulp, particularly for pulp from whole stalk and even more so for that from the woody core material, has been because of its slow drainage characteristics as shown by low initial freeness values. In this respect, these kenaf pulps are similar to pulp from rice straw that has not been thoroughly wet cleaned or bagasse which has not been depithed before cooking.

In the processing of the fibrous raw material in the project mill, it would be wet cleaned to improve the drainage characteristics of the whole stalk pulp. The pulp washing equipment surface area in the brown-stock washing system and the bleach plant would be designed to handle the more slowly draining kenaf whole stalk pulp so that the more rapidly draining bast ribbon pulp could easily be produced at a higher rate.

The screening and fiber cleaning systems for the kenaf pulp mill would be based on centrifugal principals which would serve adequately for producing either type of pulp.

7. Pulp Drying and Papermaking with Kenaf Pulps

The papermaking properties of kenaf pulps of both types have not been clearly demonstrated for manufacturing the major tonnage grades of paper and paperboard from a 100 percent furnish of these fibers on a commercial scale. The laboratory and pilot plant papermaking runs have not been made with kenaf pulps produced with modern optimum continuous pulping and bleaching processes. In addition, in most of the trials the kenaf pulp, usually that from whole stalk, has merely been used to replace some other pulp in a mixed furnish so that the specific papermaking characteristics of the kenaf pulp were somewhat obscured.

Despite the scarcity of knowledge on the commercial operation of pulp driers or papermachines using kenaf pulps, the project mill would be planned to anticipate the possible problems that could arise in running the whole stalk pulp over the dryer. The equipment would consist of a fourdrinier wet end followed by a press section with means to convey the weak wet web through to the dryer section. The dryer section would consist of can-type dryers with any necessary dryer fabrics to minimize breaks in the web.

In addition, and in anticipation of the importance for plans to convert the pulp mill into an integrated paper mill, the pulp drying equipment would be designed for minimum expense and modification requirements for conversion into a paper machine:

8. Environmental Control for the Kenaf Paper Pulp Mill

8.1. Introduction

The project mill would be designed for air and stream pollution control capabilities matching those of a modern pulp mill in developed countries.

8.2. Stream Pollution Control Facilities for the Mekong Basin Paper Pulp Mill

The project mill would be designed for maximum recycling of waste water and condensates within the process. The effluent from the mill would be treated in a primary system to remove by settling most of the dirt, fiber fines, and other solids separated from kenaf in the processing. The settled sludge would be further dewatered and used for land fill or burned in a boiler in which kenaf core material might be used as fuel.

The clarified primary effluent would then undergo a secondary treatment step in suitable aeration and impounding basins, resulting in a breakdown of the soluble organic materials which would consume oxygen if not eliminated before dumping the effluent in the receiving stream.

The effluent from the mill to the river would meet the working standards for industrial effluents discharging to inland streams as established by the Government of Thailand. It would contain no sanitary sewage or harmful or poisonous chemicals.

For the project mill, the effluent from the part of the process wherein the kenaf would be wet cleaned would not be treated. Because of its great load of oxygen consuming organic materials and fibrous debris this effluent would carry to the treating system, it would instead be used for irrigation as is done at one of the bagasse pulp mills. This would be beneficial in that organic matter, nutrients, and trace minerals washed out of the kenaf would be returned to the soil.

8.3. Air Pollution Control Facilities for the Mekong Basin Paper Pulp Mill

Although it is not planned to locate the pulp mill in an urban area where there might be public objections to traces of odors and dust, noise, and a misunderstanding that steam plumes from condensed harmless water vapor from the process are smoke, the project mill has been designed for a high degree of air pollution control in normal operation.

As the pulp mill will be designed to operate within the chemical range of a full soda process (sodium hydroxide make-up) to a full sulfate or kraft process (sodium sulfate make-up), the air pollution control system would include equipment for abating unpleasant odors which can arise when using the sulfate process. The units for odor control would be those widely used for this purpose in the pulp industry, such as a black liquor oxidation system, facilities for burning noncondensable reduced sulfur gases from the evaporators and digester blow system, an oversized black liquor recovery furnace equipped with a high efficiency electrostatic precipitator, a high efficiency Venturi-Scrubber on the lime kiln, and means for absorbing waste bleach plant gases in water going to the effluent system for further treatment.

The use of these pollution control systems would leave the area adjacent to the mill suitable for other industrial or agricultural enterprises.

CHAPTER VIII - FINANCIAL ASPECTS OF KENAF PRODUCTION FOR PAPER PULP MANUFACTURE

1. Farm Revenue from Kenaf Textile Fiber Production in Northeast Thailand

Farm level prices for Mixed Grade retted fiber averaged \$2.30/kg. (\$0.115/kg.) during the most recent 5-year period and stood at \$2.46/kg. (\$0.123/kg.) for the 1974/1975 season. In an attempt to reverse the recent decline in kenaf production, the Thai bag and hessian mills established guaranteed minimum

fiber prices equivalent to a farm gate price of ₦2.75/kg. (US\$0.138/kg.) for Mixed Grade in April 1975 and increased this to a farm gate price equivalent to ₦3.25/kg. (US\$0.1625/kg.) in July 1975. At the latter price level and on the assumption of an average retted fiber yield of 184 kg./rai (1,150 kg./ha.), the farmers' gross revenue would amount to ₦598 or, say, ₦600/rai (US\$187.50/ha.).

2. Estimated Farm Prices of Kenaf Pulping Raw Materials

Although the grower will expend from 40 to 45 percent less costs and labor on the production of kenaf stalks (whole or chopped) for sale to the pulp mill compared to retted kenaf production for sale as textile fiber, this Study assumes that his gross revenue must remain at the same level to provide him with the necessary production incentive, particularly in competition with tapioca. On the basis of a 1,200 kg./rai (7,500 kg./ha.) field dry whole stalk yield, the price payable for one metric ton of such stalks would then have to be ₦498 (US\$24.90), delivered local collection center. It is noted that, at a stalk yield of 1,500 kg./rai (9,375 kg./ha.), this cost would be reduced by one-fifth to ₦400 (US\$20.00) per metric ton,

For kenaf bast ribbon, a 10 percent increase in gross revenue is assumed to provide the required incentive to induce the farmer to carry out the additional stripping operation. At a bast ribbon yield of 340 kg./rai (2,100 kg./ha.), the price payable for one metric ton of field dry ribbon would then have to be ₦1,935 (US\$96.75) delivered local collection center.

2.2. Western Hemisphere Kenaf

H. cannabinus is expected to produce about twice as large yields as H. sabdariffa but it will require some increased expenditures, particularly on selected seed and on fertilizer, so that its adjusted gross revenue will not be twice as much but only some two-thirds greater. In addition, since H. cannabinus must be planted on more fertile soils on which the farmer would have the alternative to grow a higher value crop, this Study assumes (most conservatively) that the pulp mill will pay the same stalk and ribbon prices, per field dry metric ton delivered local collection center, for both kenaf species as follows:

Whole Kenaf Stalks	= ₦ 498 (US\$24.90)/FDMT;
Kenaf Bast Ribbon	= ₦1,935 (US\$96.75)/FDMT.

3. Kenaf Raw Material Purchasing and Handling Cost Estimates

3.1. Pulp Mill Procurement Organization

For whole kenaf stalks, the average collection center costs of purchasing, weighing, stacking, waterproof cover protection, and destacking, rebundling and loading into trucks for transport to the pulp mill are estimated at \$45.00 (US\$2.25)/FDMT.

To establish a pulp mill operated chopped whole stalk purchasing and baling organization would require an estimated capital investment in baling plant and allied facilities of some ₦45 million (US\$2.25 million) and, at an estimated baling cost of ₦48 (US\$2.40) per chopped stalk material bale, an annual operating expenditure of some ₦54.4 million (US\$2,720,000).

For bast ribbon purchasing and baling, a somewhat smaller capital investment of about ₦35 million (US\$1.75 million) and annual operating costs of some ₦42.2 million (US\$2,110,000) would be required, if the ribbon is to be procured by the mill itself.

3.2. Procurement Through Kenaf Baling Plants and Traders

This procurement system would eliminate all capital investment requirements by the pulp mill, since the established kenaf baling plant facilities would then be utilized. Furthermore, it is anticipated that the balers would be willing to bale stalk chips or bast ribbon on contract at a rate of about ₦20 (US\$1.00) per bale. Allowing for reasonable storage charges at the baling plants, it is suggested that the same ₦45 (US\$2.25)/FDMT of handling costs estimated for the mill operated collection centers be set aside for the balers but that including the baling charges.

3.3. Procurement Through Cooperative

If the cooperatives were to establish their own baling plants, the capital and operating costs would be the same as those estimated for a mill operated procurement organization and it is suggested that it would be to their advantage to contract for baling with the established baling plants.

4. Kenaf Raw Material Transportation Cost Estimates

Based upon the bulk densities and average lead distances established for the various types of kenaf pulping raw material in this Study and upon a brief survey of Government and private firm trucking rates, the following transportation costs per field dry metric ton from the collection centers to the mill yard have been calculated:

	<u>₪</u>	<u>\$</u>
A. Whole Stalks:		
Field Bundled	136.00	6.80
Press Baled	52.00	2.60
B. Chopped Stalks:		
In Bulk	208.00	10.40
Press Baled	45.00	2.25
C. Bast Ribbon (Press Baled)	90.00	4.50

5. Kenaf Raw Material Cost, Delivered Mill Yard Gate

The total costs, rounded off, of the various types of kenaf raw material, delivered to the pulp mill yard gate, are then summarized as follows:

	<u>Cost/FDMT</u>	
	<u>₪</u>	<u>\$</u>
A. Whole Kenaf Stalks:		
Field Bundled	680.00	34.00
Press Baled	600.00	30.00
B. Chopped Kenaf Stalks:		
In Bulk	750.00	37.50
Press Baled	590.00	29.50
C. Kenaf Bast Ribbon(Press Baled)	2,080.00	104.00

6. Pulp Mill-Demonstration Farm

Detailed capital cost, operating cost, profit & loss and cash flow estimates are presented for a 240 ha. Demonstration Farm Unit and for the whole stalk, chopped stalk and bast ribbon production alternatives respectively and these may be summarized as follows:

	<u>Whole Stalks</u>	<u>Chopped Stalks</u>	<u>Bast Ribbon</u>
Capital Costs:			
1st. Year	\$189,135	\$179,015	\$363,360
2nd. Year	12,780	12,550	27,380
Operating Costs (Per Year)	73,345	70,405	96,150
Production Costs/FDMT	24.00	22.90	146.10
Suggested Sales Price/FDMT	28.80	27.50	175.30
Investment Repayment Period	10 years	11 years	15 years

CHAPTER IX - ESTIMATED PRODUCTION COSTS, CAPITAL REQUIREMENTS, PROFITABILITY; AND ECONOMIC VALUES OF A KENAF PAPER PULP MILL IN THE MEKONG BASIN AREA

1. Introduction

In a pre-feasibility study for an undertaking of the magnitude of the kenaf paper project in a developing country, it is essential that there be not only a realistic appraisal of all the technical factors but of the financial and economic aspects as well. There have been far too many projects in both developed and developing countries where faulty engineering planning and underestimation of capital investment requirements and manufacturing costs have resulted in great and continuing difficulties for a new enterprise. For this reason, a very detailed financial analysis has been made for the kenaf project mill.

2. Development of the Estimated Production Costs of the Mekong Basin Project Kenaf Pulp Mill

It has been estimated that approximately 781 local workers, including 320 of them in the kenaf storage and handling area of the

mill, would be employed. In addition, the services of a foreign technical assistance team for a period of the first four years of mill operation have been included in the costs for labor. Including all perquisites, salaries, and wages, it has been estimated that the labor cost for the project mill would be $\text{฿}303/\text{ADMT}$ (US\$15.15/ADMT) of bleached pulp product after the departure of the foreign technical assistance team.

Estimates of direct production costs at full operating rate have been developed for both kenaf whole stalk and bast ribbon bleached pulps. These estimates have been based on the kenaf fibrous raw material costs developed in the agro-economic sections of this Study, the cost of chemicals and fuel at the mill site in Northeast Thailand, labor costs, maintenance and operating materials and supplies, contingencies, and fire insurance on kenaf in the mill storage yard.

The direct production costs have been estimated to be US\$181.74/ADMT for whole stalk pulp and US\$331.91/ADMT of pulp for the bast ribbon type.

The cost of products sold, based on the direct production costs, selling expense, prepaid freight on pulp, insurance of fixed assets, and the business tax, have been estimated to be US\$239.03/ADMT for whole stalk pulp and US\$403.33/ADMT for the bast ribbon pulp.

These costs have been based on the plan that the pulp mill would use lignite mined in Thailand as the most available and lowest cost fuel. If imported oil were used as the fuel, US\$34.44/ADMT would have to be added on to the cost figures. It has been planned that the project mill would generate all the necessary steam and power, including that required by the townsite.

3. Estimated Total Capital Requirements to Establish a Kenaf Paper Pulp Mill

For estimating the total capital requirements of the project mill, budget quotations at 1975 price levels were obtained on the major pieces of equipment that the mill would use. From this information, it was estimated that total machinery and equipment, delivered to the mill site, would cost US\$32,300,000 in foreign currency and US\$6,400,000 in local currency for a total of US\$38,700,000.

For land, site development, and plant buildings and structures there would be required US\$550,000 in foreign currency and US\$6,250,000 in local money.

All other items to be capitalized for the plant, such as spare parts and consumables, erection labor, materials, and supervision, engineering and technical services, personnel training abroad, prestart-up and start-up expenses, contingencies, and interest during construction were estimated to require a capital of US\$20,900,000 in foreign currency and US\$8,300,000 in local money for a total of US\$29,200,000.

The total of the foregoing capital requirements for implementing the pulp mill was US\$53,750,000 in foreign currency and US\$20,950,000 in local money for a total of US\$74,700,000. When the local capital for the housing community of US\$3,357,000 is added, the total cost of the fixed assets becomes US\$78,057,000.

Inclusion of working capital of US\$3,227,000 results in an estimated total capital required to establish the "turn key" project for whole stalk pulp at start-up of US\$53,750,000 from foreign funds and US\$27,534,000 from local sources for a total of US\$81,284,000. If the mill would pulp only kenaf bast ribbon, the additional working capital required for the inventory of kenaf at the mill would be US\$2,617,000. However, in the financial projections it was assumed this would be borrowed at 10 percent interest from local sources and would be repaid as soon as possible from funds generated by the mill.

Based upon these estimates that the local funds would be 33.87 percent of total capital requirements, this was chosen as the amount of equity to be put up by the owners of the mill during the period before the start of commercial operations. This 2:1 debt to equity ratio was judged to be more than adequate to obtain favorable terms for financing from foreign or international agencies for the balance of the total capital requirements.

It is interesting to note that the total capital requirement of US\$406,000/ADMT/day of pulp that has been estimated is only slightly less than the US\$425,000 for this size of "turn key" kenaf pulp mill when read from the general curve for total investment requirements discussed in Section 6.2. of Chapter I and attached hereto.

4. The Estimates of Profitability for Kenaf Paper Pulp Mills

In developing profit and loss statements for this project, it was assumed that interest of 10 percent would be paid on the foreign loan, with the first interest payment due on the theoretical start-up date of the mill. Thereafter, at 6 months intervals, interest would be paid and the principal would be paid off in 20 installments over a 10 year period.

This interest rate and period for debt repayment were used because it was judged that foreign lenders would require this in view of the inflationary forces at work in the economy of the world.

Depreciation on the "straight line" basis of 20 years for buildings and structures and 15 years for machinery and other capitalized items have been used in view of the favorable income tax holiday granted by the Thai Board of Investment for Promoted Enterprises in the Special Investment Zones. Two other important items in the financial analyses are the following:

Pulp Price

For the financial projection for the kenaf whole stalk pulp mill, it was assumed that this product would be priced at US\$450.00/ADMT delivered to a paper mill in Bangkok. This was estimated to be competitive with the total price, duties and handling costs for bleached hardwood market pulp in Thailand at the end of 1975.

In the financial projection for the kenaf bast ribbon pulp project, consideration had to be given to the fact that the fibrous raw material cost for the bast ribbon would be US\$160.65/ADMT of pulp higher than for whole stalk pulp. Therefore, to show a mill of approximately the same financial viability as for whole stalk pulp, the delivered sales price of the bast ribbon pulp was increased to US\$600.00/ADMT. This is approximated US\$130.00/ADMT higher than the bleached softwood market pulp was costing, delivered in Thailand, at the end of 1975.

The use of this price for the bast ribbon pulp was also based on the fact that the national and regional benefits of such a project as planned for Northeast Thailand would justify the imposition in its favor of an import duty of about 28 percent of the C.I.F. value against imported softwood pulp.

Inflation Factor

Additional estimated profit and loss statements for the kenaf pulp mill have also been made in which an average inflation factor of 3 percent per annum was used. This type of "indexation" estimate, which is coming into use more in the business world, shows the effect of long term escalation of prices and costs in relation to the initial fixed debt of the project and the interest paid on it.

It is not only important to show the effects of inflation in a financial projection but the time value of the money invested in the project as equity by the owners must be considered in the profitability analysis covering a projection period of 15 years of operation of the mill. In this Study, the profitability of the projects has been determined on the Discounted Cash Flow (DCF) basis in which return on equity put into the project before start-up of commercial operations is also given equal consideration along with value of working capital and of the mill at the end of the projection period. This is believed to be the most realistic way to appraise the financial aspects of this project. However, for comparison purposes, the different calculations used in this Study and estimates of project profitability were as follows:

Kenaf Pulp Type	Inflation Factor (%)	Payback Period (Years)	<u>Average Annual Return on Basis of</u>		
			<u>Total Investment (%)</u>	<u>Owners' Equity (DCF) (%)</u>	<u>Equity (%)</u>
Whole Stalk	0	7.55	14.1	35.0	16.9
	3	6.76	20.3	53.1	20.4
Bast Ribbon	0	7.75	13.5	34.6	16.4
	3	6.90	19.3	52.3	19.9

The Payback Period measures the rapidity of return of the capital investment. It is not considered a proper expression of profitability because it ignores earnings beyond the period, the time value of money, and the residual value of the mill and working capital.

The return on Total Capital Investment does not take into account the timing of money flows and is considered to be suited only as a secondary expression of profitability.

Simple expression of the Return on Equity is considered misleading for this profitability analysis because it ignores the time value of money and the years prior to start-up when most of the equity investment would be made. However, when Return on Equity is expressed on the Discounted Net Cash Flow basis which removes payment of the foreign debt from the Gross Cash Flow, a realistic financial appraisal of the project's value to the owners is obtained.

In the case of the kenaf whole stalk pulp mill selling its product at the competitive market price for imported hardwood pulp in Thailand, the Rate of Return on Equity (DCF basis) of 16.9 percent per annum is very favorable.

However, the kenaf bast ribbon pulp has such a high fibrous raw material cost in comparison with the kenaf whole stalk pulp that to achieve the same approximate profitability it would have to sell for US\$600.00/ADMT or US\$150.00/ADMT more than the latter product. This sale price for the bast ribbon pulp is about US\$130.00/ADMT higher than for the technically competitive bleached softwood sulfate pulp imported into Thailand at the present time.

5. The Economic Values of the Various Kenaf Pulp Project Options

The financial projections of this Study show the important long range economic benefits which would result from establishing the kenaf pulp mill in the Mekong Basin. As an example, the kenaf whole stalk bleached pulp mill project, without any consideration given to the factor of inflation, would produce in the following benefits:

Employment

At least 780 people directly employed in the mill.

At least 2,400 supportive and service jobs in nearby communities.

Full or part time employment of an estimated 20,000 families in the agriculture sector to grow, harvest, and transport kenaf.

Creation of new jobs for producing and transporting chemicals and fuel to the mill and transporting the pulp products.

Jobs of several years duration to build the mill and equipment from local sources.

Local Expenditures

A total expenditure of ¥486,140,000 (US\$24,307,000) for local goods and services during the construction of the mill.

An average annual expenditure of ¥288,280,000 (US\$14,414,000) for local goods and services out of a sales revenue of ¥611,100,000 (US\$30,555,000) per year.

Taxes

A considerable amount of taxes resulting from new business activity and on income to those supplying goods and services to the mill and on dividends to stock-holders would be paid.

A business tax averaging ฿30,280,000 (US\$1,514,000) per year on sale of products would be paid.

Corporate income tax averaging only ฿7,920,000 (US\$396,000) per year would be paid due to favorable tax incentives for Promoted Enterprises in Northeast Thailand.

A loss of duties and other taxes on imported pulp amounting to ฿16,840,000 (US\$842,000) per year would result.

Foreign Exchange Savings

During the financial projection period, the annual average payout of foreign exchange would be US\$6,384,000 for repayment of foreign debt and the interest on it, for the services of the Technical Assistance Foreign Team, and for imported spare parts and supplies.

Foreign exchange for the purchase of hardwood pulp amounting to US\$29,537,000 per year on the average would be saved. Therefore the net saving of foreign exchange would be US\$23,153,000 annually.

6. The Financial Viability of the Kenaf Pulp Project Options

The results of this Study indicate that the kenaf whole stalk bleached pulp mill would be economically viable at the present prices paid for hardwood bleached sulfate pulp imported into Thailand.

However, a serious local competitive situation could result if proposed bagasse/bamboo pulp/paper mills are implemented. It has been estimated that bagasse bleached pulp could be sold in Thailand for as much as ฿852/ADMT (US\$42.60/ADMT) less than the kenaf whole stalk pulp due to its lower cost for fibrous raw material. This would be the case where lignite is the replacement fuel for bagasse at the sugar mill and is used for fuel at the pulp mill.

Despite this specific situation, it should be considered that the kenaf pulp mill would furnish additional employment in the agricultural sector of the Mekong Basin which the bagasse pulp mill would not do. It would also stabilize the market for kenaf in that area.

In the case of kenaf bast ribbon pulp, it would have to sell for about 33 percent more than the whole stalk pulp for the mill to have equivalent financial viability. This higher price for kenaf bast ribbon pulp would require that a duty of about 29 percent of the C.I.F. value would have to be imposed on softwood bleached sulfate pulp imported into Thailand to make the two pulps competitive in price.

Although the mill as designed would produce either type of kenaf pulp, it appears that kenaf whole stalk pulp would be the better product option, if the entire production of the mill could be marketed at the sales price used for the financial projections of this Study.

CHAPTER X - DEVELOPMENTAL ACTIVITY REQUIREMENTS

1. Introduction

The further investigative, research and pilot program activities deemed necessary prior to large-scale kenaf based pulp and paper mill project implementation are discussed and the Draft Terms of Reference for a follow-up development program are established.

2. Agro-Economic Aspects

2.1. Agronomic Considerations

Variety testing and selection will have to be one of the basic development program concerns and should include both the local and newly introduced kenaf varieties. These activities should be complemented by investigations into land preparation methods; time-of-planting and planting method trials, the latter with particular emphasis on planting implements and planting distances; fertilizer trials under different soil conditions; weeding and seedling thinning for the *H. sabdariffa* species; pest and disease control investigations, prominently including rootknot nematode problems with respect to *H. cannabinus* planting areas; production and processing of improved seed; rotation crop trials and soil conservation measures; and a detailed survey of potential kenaf for paper pulp production areas in the Lower Mekong Basin area.

2.2. Crop Harvesting, Processing and Handling

Investigative activities under this heading must include the establishment of optimum harvesting periods and feasible harvesting period ranges for whole stalk, chopped stalk and bast ribbon production respectively; harvesting method and procedure tests, both manual and mechanized, again for the three types of kenaf pulping raw material and including stalk chopping and bast ribbon stripping; detailed and exhaustive analyses of stalk and bast ribbon yields and of stalk composition; field drying and field and production area storage alternatives; field and high-density whole stalk, chopped stalk and bast ribbon baling; and investigations into kenaf raw material transport from the production areas to the pulp mill yard gate.

2.3. Agri-Economic Development Program Implementation and Evaluation

The proposed agro-economic development activities should be implemented through a combined research and pilot scale program which, in turn, must be closely coordinated with the ongoing local kenaf research efforts. In view of the large potential savings to the pulp mill by even minor kenaf yield improvements, development program financing might be assigned to the mill project. The research program should follow the already well established investigative procedures, and the pilot program - possibly organized along Demonstration Farm lines - should aim at duplicating commercial methods, although obviously on a limited scale of the order of 80 ha. (200 acres - 500 rai). Subsidiary small-scale research and pilot programs would have to be carried out in each major kenaf for paper pulp production area, again in close cooperation with the local agricultural research authorities.

Thorough evaluation of the research and pilot programs would be undertaken upon completion of the first season.

2.4. Draft Terms of Reference, Additional Development Program

Detailed proposed Terms of Reference for further investigative activities of the agro-economic project aspects as required to complement and confirm the conclusions and recommendations of this present Pre-Feasibility Study are listed.

Development of Equipment and Processes for Separating
Kenaf Stalk Fiber Components Before Pulping

Systems for wet or dry separation of the woody core material and the bast ribbon from the whole stalk would be very much worthwhile and should be developed.

Study of Equipment and Processes for Fractionating
Kenaf Stalk Components After Pulping

An investigation should be made of partial or complete fractionation of the long and short fibers in whole stalk kenaf pulp, preferably before bleaching. If a use could be found for the short fiber pulp, the cost of the bast ribbon type might be lowered significantly.

Development of Newsprint from Kenaf

There is a possibility that kenaf whole stalk mechanical, thermo-mechanical, or chemimechanical pulp or mixtures of these could be used for 100 percent of the fiber content. This would eliminate the need for chemical pulp as about 10 percent of the furnish with groundwood in newsprint. The use of woody core material for these grades of pulp in newsprint, low cost printing and writing papers, and tissue and towelling grades should be explored. A pre-feasibility study for newsprint based on kenaf should also be made.

Investigation of Kenaf for Particleboard

The woody core material should also be investigated by the laboratories of the international firms which build particleboard machinery and a pre-feasibility study should be made for production of this product when the full feasibility study is made for the kenaf paper pulp mill.

CHAPTER XI - PROJECT ORGANIZATION AND MANAGEMENT

1./2. The Kenaf Raw Material Supply

This Study has concluded that, for the Mekong Basin project mill, the kenaf raw material will continue to be produced by small holders and that it will be supplied to the mill through farmers cooperatives as well as through the established kenaf dealers and traders, and that in the form of whole stalks or separate bast ribbon and core material. This production and supply method limits the required intervention by the mill to that of a Procurement Office.

In addition, this Study envisages the establishment, by the mill, of one or more Demonstration Farms which will be staffed by mill employed supervisory personnel and labor and which will serve as research and seed production centers in addition to their function of demonstrating improved kenaf production practices to the small holders and of serving as bases for mill organized extension services. It is estimated that the cost of organizing and operating such demonstration farms and services will be recovered many times over through raw material cost savings resulting from increases in kenaf yields.

3. Paper Pulp Production

3.1. Introduction

It has been recognized that full scale commercial runs of kenaf pulps for papermaking trials are required before there can be assurance that kenaf pulps could replace pulps from wood, bamboo, and bagasse for market. There would be a better possibility for bringing this about if there could be a worldwide coordination of the work on kenaf for paper pulp.

If such actions are taken as the preliminary step in the development of the Mekong project mill, then the proposed agro-economic studies should be made at or near one of the suitable primary pulp mill sites located in this investigation. This would assure the possibilities of fibrous raw material supplies for the pulp mill project.

3.2. The Executing Agency

Due to its cooperative and efficient handling of the contract for the present pre-feasibility study and its long term and continuing responsibilities for planning and guidance for projects in the Mekong Basin, the logical choice for Executing Agency for further studies on kenaf paper pulp would be the Committee for Coordination of Investigations of the Lower Mekong Basin. The worldwide significance of these studies on kenaf pulp is such that supporting grants might be obtained from the United Nations Development Programme, the World Bank and the Asian Development Bank, as well as the Governments of Thailand and other riparian countries. This would be a particularly good opportunity for agencies of the U.S. Government to help bring to commercial application the great amount of research and pilot plant work on kenaf growing and pulping by the U.S. Department of Agriculture.

3. Consulting Services for the Pulp and Paper Development Studies

In contrast with the agro-economic studies for a future project, the pulp and paper development studies will have to be carried on outside the Mekong Basin proper because there are no suitable facilities available for such investigations in that area. Kenaf grown in some other locations would be comparably suitable for the commercial production tests or baled kenaf could be shipped from the Mekong Basin. Therefore, the choice of an existing pulp mill for the tests should be made on the basis of the one which would be the best equipped to process such nonwood plant fibers.

The technical consulting and management services for the pulping trials and marketing tests should, preferably, be supplied by an independent consulting firm that would not be directly involved later on in owning part of the mill or promoting it, as a contractor in building it, or in furnishing equipment and detailed engineering services for the project. This would allow complete objectivity on the part of the consultant in choosing the best combination of equipment and processes for the mill when the final feasibility study is made in continuation of the next investigation. The consultant to carry on these studies would be chosen on the basis of experience in the processing and pulping of nonwood plant fibers.

4. Pulp and Paper Mills for Commercial Trials with Kenaf

There are at least two nonwood plant fiber pulp mills in the Southeast Asia Area which have facilities for producing kenaf pulps under commercial conditions. These are the Siam Kraft Paper Co., Ltd. in Thailand and the United Pulp and Paper Co. (UPPC) in the Philippines, both pulping bagasse. Kenaf chopping and fiberizing equipment would have to be installed at these mills before they would be in a position to produce unbleached kenaf pulps.

The Siam Kraft paper mill could produce linerboard and bag papers and the UPPC mill could produce extensible multiwall bag papers using the Clupak unit. Wet lap or wet pressed pulp could also be produced and transported to other mills where bleaching equipment and facilities for making printing and writing and tissue grades of paper would be available.

In addition to the excellent laboratory facilities at these two companies that would be used for the commercial pulp and papermaking studies, the pulp and paper laboratory of the Research Division of the Department of Science of the Ministry of Industry in Thailand could serve adequately for the physical and chemical analyses and laboratory pulping trials needed for screening the kenaf samples produced in the agro-economic development trials of future studies.

Fig. I.1.

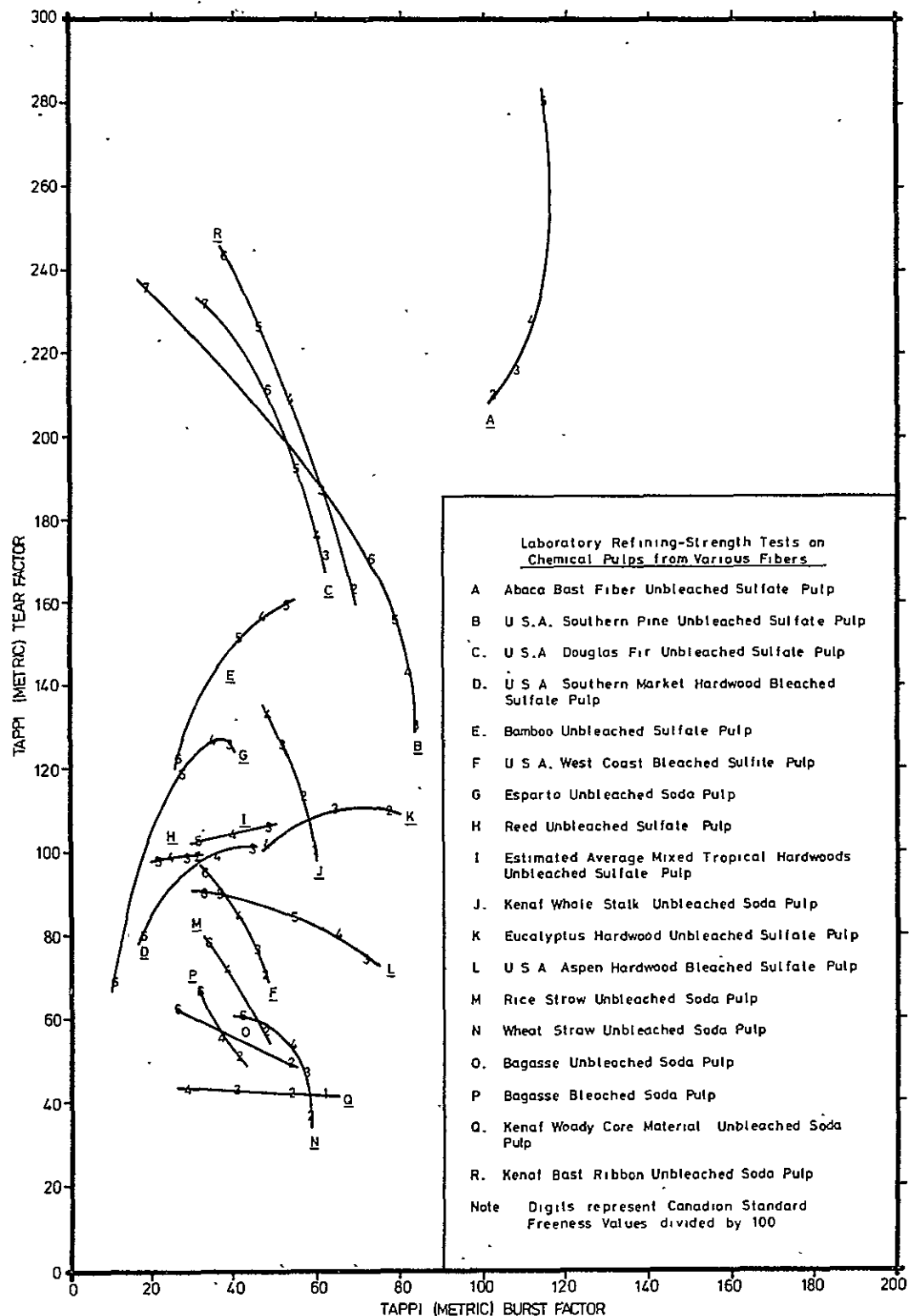
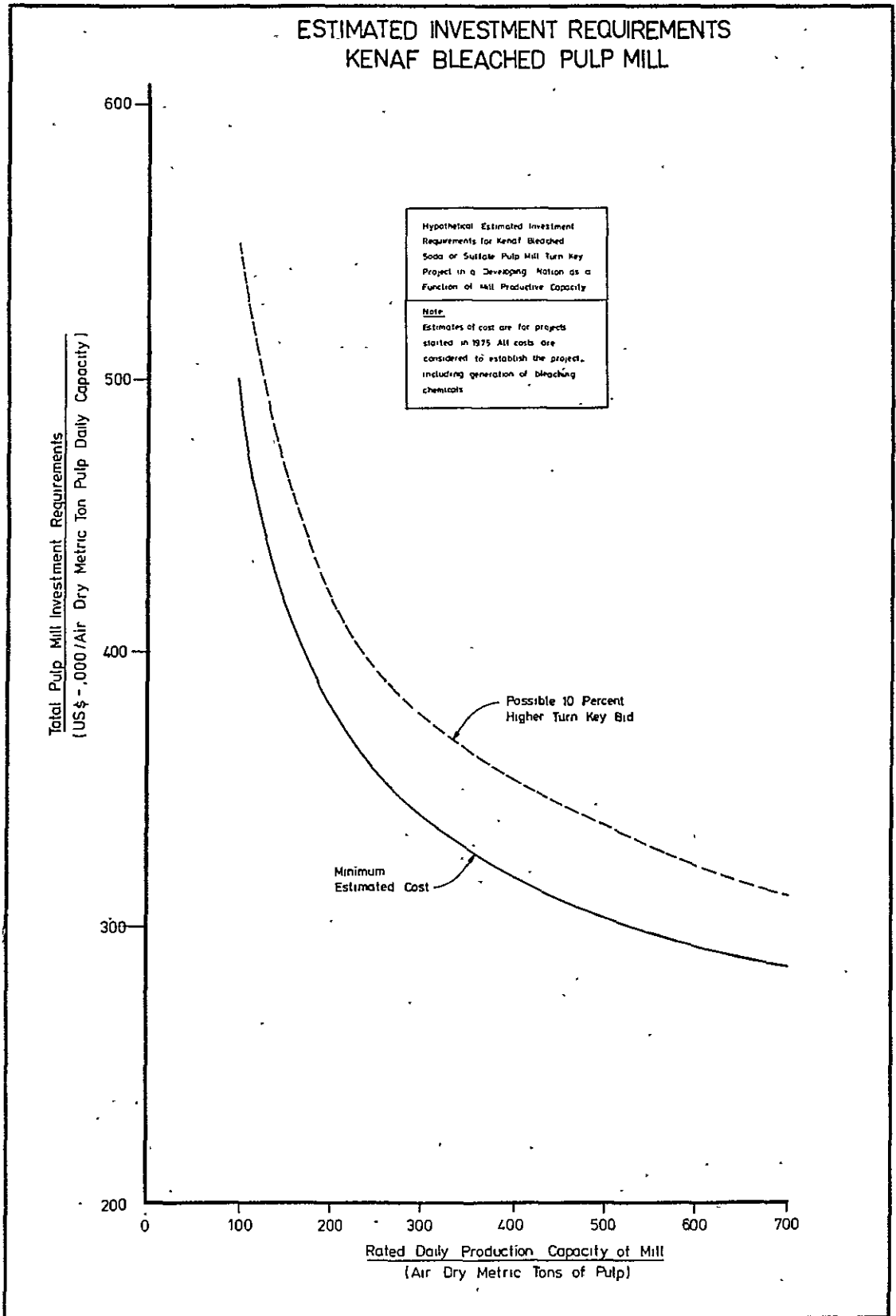


Fig. I.2.



CHAPTER I - THE USE OF KENAF FOR PULP AND PAPER

1. Early History of Kenaf as a Raw Material for Pulp and Paper (1950-1960)

Kenaf is a tall woody annual plant that was reportedly (1,2) cultivated in West Africa earlier than 4000 BC. It has been used for many centuries by the inhabitants of Asia and Africa for food, animal forage, and fiber and was mentioned (3) in the technical literature on fibers as early as 1763. Kenaf bast fiber as an acceptable substitute for jute in the manufacture of burlap, sacking, rope, twine, and carpet backing was reported (4) to have been commercially adopted about the middle of the nineteenth century.

Prior to 1950, at the time of publication of a bibliography (5) on the use of bast fibers for papermaking, there were no published studies on the use of kenaf for paper pulp. In view of this, the general literature survey by the Consultants for the review sections of this report started with the year 1950 and, to date, has turned up more than 700 references, mostly on the agronomic aspects of kenaf and the preparation and use of its bast fiber for textiles and cordage.

This voluminous literature published in the last 25 years on the subject of kenaf indicates that much, though not on pulping kenaf, was also written prior to 1950. Undoubtedly, there is a tremendous amount of information available for an extensively documented technical review of the general subject of kenaf, if its preparation could be financially supported.

The detailed literature search on paper pulp production from kenaf for this report, beginning with the year 1950, has shown a rapidly accelerating research and commercial interest marked by the beginning of technical studies on this fibrous raw material on the part of many industry laboratories and Government and university research organizations. Of the many significant technical references on kenaf paper pulp published in the 25 year period to date, only four can be considered work in the decade representing the 1950's. The rate of publications for the first five years of the 1970's indicates that the number of studies in the present decade could perhaps triple those of the 1960's which were several times those of the beginning period.

In addition, there are undoubtedly numerous industrial investigations of a confidential nature made on kenaf for paper pulp that have not been publicly noted or reported upon or made available to the Consultants for this review. However, in this review there have been considered more than one hundred technical papers on kenaf pulping that are available and either published or considered to be in the public domain for reference. In addition, any unpublished material which has been released by cooperative research organizations has also been considered for this review. This information is reviewed in general in various sections of this study and in the following discussions of the activities of the organizations that have carried out the studies on kenaf for paper pulp.

It is surprising that published studies on the use of kenaf for paper pulp did not begin earlier than indicated by the literature record. Its bast fiber was known for years as a logical substitute for the jute bast fiber for textile uses. Jute, mostly in the form of textile wastes, had also been used for many years before 1950 to make high strength paper pulps. Kenaf's woody core was obviously a substitute for the jute sticks and hemp hurds left over from bast fiber production and which were being experimentally pulped in various parts of the world prior to 1950, as reported in early technical literature of the pulp and paper industry.

The first published record of kenaf paper pulp is its significant listing as Sample No. 1 in the TAPPI Library (6) at the Institute of Paper Chemistry for which collection efforts for pulp samples from all types of fibrous raw materials were initiated in October 1949. This sample was designated as Ambari hemp (Hibiscus cannabinus) (sic) unbleached soda pulp from India, but evidently was H. sabdariffa because of the common name given.

The next reference to kenaf pulp was by Lathrop and Nelson (7) of the Northern Regional Research Laboratory (NRRL) of the U.S. Department of Agriculture (USDA) in 1954. This laboratory had, over a period of time, been collecting and analyzing samples of the various imported leaf and bast fibers used commercially for manufacturing specialized, high strength papers for many years. For comparison in the chemical analysis, they included several bast fibers then being grown and/or investigated in the United States, including kenaf from the Everglades Experiment Station in Florida. At that time, there existed already a considerable body of knowledge on the pulping properties of the bast fiber plants such as ramie, hemp, jute and flax, but not of kenaf.

Because of the favorable trials with and field yields obtained from growing kenaf as a crop in various parts of the United States, scientists at the NRRL considered kenaf one of the most promising possibilities for a supply of fibrous raw material for paper pulp production in the United States. Their studies encompassed laboratory pulping trials on both kenaf bast ribbon and the decortication waste containing some woody core material of the stalk. These pulping tests were made using the Mechano-Chemical (M-C) process which had been developed by the NRRL particularly for nonwood plant fibers. Although the pulping tests on kenaf were of limited scope, the data indicated it would be practical to pulp either of these materials by the obsolete M-C process. This consists of pulping with caustic in a Hydrapulper at 98°C and atmospheric pressure rather than cooking under pressure as is done in modern mills to produce higher quality pulps than can be produced with the M-C process.

As a further indication of the growing interest of scientists of the USDA in the use of kenaf, Chidester and Schafer (8) published a report in 1961 on the pulping studies of woods and nonwood fibrous plants including kenaf from Asian and Australasian countries. These tests were made at the Forest Products Laboratory over a period of 33 years. H. cannabinus samples from the Philippines tested were whole stalk, depithed stem, and decorticated fiber tow. The depithed stalk and whole stalk samples were found to be difficult to pulp, requiring a high alkali charge and prolonged cooking time, and produced somewhat lower yields than could be obtained from wood. The kenaf tow cooked much more easily with normal chemical consumption and gave excellent yield, thus indicating at this early date the outstanding superiority of the kenaf bast fiber, as compared to whole stalk or decortication waste, for full chemical pulping.

Prior to 1960, there was little or no commercial interest publicized on pulping the bast fiber fraction of kenaf in spite of its resemblance to jute fiber. However, in connection with agricultural developments in Argentina and a pulp/paper mill being developed there to make bleached printing and writing papers, primarily from bagasse, Atchison (3,9) proposed as early as 1959 that kenaf bast ribbon pulp be produced in the same system used for bagasse pulping and to eliminate the expected need for imported bleached softwood sulfate pulp for the long fiber portion of the papermaking furnish. Had that program been followed, the technique of pulping of both bast ribbon and whole stalk kenaf would have been commercially established ten years ago, based on the general knowledge of pulping nonwood plant fibers available at that time. This would have eliminated the need for many of the laboratory pulping studies on kenaf in the interim years.

However, because that important full scale industrial step was not taken at that time, it has been necessary for the scientists working seriously in laboratories all over the world to continue most of their pulping studies on a bench scale in order to demonstrate to the paper industry that kenaf is a technically suitable fibrous raw material for paper pulp. With the serious limitations on their studies imposed by the use of small capacity batch laboratory equipment, as compared to the modern continuous pulping equipment most favorable for pilot plant trials and for commercial operation and economical production, the work of laboratories investigating kenaf pulping on a commercially oriented basis, and beginning around 1960, has only recently been applied in full scale mill trials. In these, and with only one exception, whole stalk kenaf has been pulped and bleached in batch equipment representing older operating practices. These pulps have been used as part or all of the fibrous furnish for a few papermaking runs of limited duration.

It is in the light of this situation at the present time that the published technical developments on kenaf for paper pulp by the various agricultural research agencies and laboratories around the world are outlined in the following section.

2. A Review of Worldwide Experience in Harvesting, Transporting, Storing and Pulping of Whole Kenaf and Kenaf Components for Paper Pulp

2.1. Introduction

Up until the present time, the agencies and laboratories studying kenaf for paper pulp, other than those of the USDA, have not published detailed studies on the problems of the logistics and the costs of harvesting, transporting, and storage of either whole stalk or bast ribbon kenaf in the large quantities required for year around operation of a large pulp mill of reasonable economic size. In most of the studies reported so far, other than those by the USDA, for large scale, mechanized harvesting of kenaf, the limited assumptions appear to have been made that bundles of field dried kenaf stalks would be delivered by truck to the pulp mill and stored in the open or under cover.

Although reasonable for a small mill near the supply of kenaf, this is unrealistic for large scale pulp production and the agro-economic sections of this report will explore this subject in technical detail as it applies to providing the kenaf raw material supply for a pulp mill which might be built in the Mekong Basin area.

For the planning and establishment of a pulp mill based on kenaf under modern, competitive conditions, there is the greatest necessity that these questions be answered, the process problems solved, and the required equipment developed or adapted to transfer the standing kenaf from the field to the digester at the pulp mill at minimum papermaking fiber losses and lowest costs.

The Consultants recognize, on the basis of information available, that at this time it will be far more meaningful for the future development of kenaf pulp mills to work out the lowest cost systems for supplying a year around continuous flow of kenaf raw material to the pulp mill process rather than to carry out more laboratory batch pulping trials on green or field dried whole stalk or bast ribbon kenaf. Because of this, the Consultants believe that the agro-economic studies in this report will be valuable for planning paper pulp projects in all parts of the world where kenaf can be grown.

There is a good historical example of the importance of first solving the basic problems relating to the growing, harvesting, and processing of a fibrous raw material being developed for a new large

scale industrial use in new areas. This is the present case with kenaf for paper pulp in the United States or any other area where it is not already grown economically for textile purposes. Allison (10), Fishler (11), and White et. al. (12) have reviewed the problems encountered by the U.S. Government in trying to develop commercial kenaf crops in the Western Hemisphere during World War II and the Korean war. This was to produce replacement fiber for jute which would not grow in the United States and had to be imported at a time of high prices and short supply. Under a very ambitious program starting in 1943/1944, kenaf bast fiber was selected as the most promising substitute for jute for textiles and the U.S. Government gave very substantial encouragement in the form of research, subsidies, stockpiling, marketing, etc. to potential growers and producers of kenaf in Central America, the Caribbean area, and Florida.

Because the actual growing of kenaf was found to be simple at first, most of the agronomic effort was devoted to maximum yield of fiber encouraged by favorable Government price supports. However, the agronomic studies had not indicated all potential hazards in the prior research and a large part of the crop was unexpectedly destroyed by diseases and pests. In addition, the lack of developed practical equipment for harvesting and processing the crop resulted in failure of the commercial projects in Florida and several Latin American countries.

Partially as a result of the setback due to lack of time to discover and solve these problems on a comprehensive pilot scale before establishing full commercial projects, there have been no appreciable commercial plantings of kenaf for textile purposes since 1952 in the United States. The Florida research effort on kenaf for cordage was finally terminated in 1965 because the prospects for commercializing the crop for this purpose in the United States did not appear promising. However, the cooperative research program has had a beneficial impact on kenaf production in other countries. Furthermore, at various branches and affiliates of the USDA the agronomic studies have been continued and extensive investigations have been made on the harvesting, storage, and preparation of kenaf fiber for paper pulp as well as on pulping requirements. These continuing studies should result in realistic answers as to the economic viability of kenaf for paper pulp in the United States. At the same time, these investigations will help provide the technical process basis for paper pulp manufacture in the developing countries where kenaf is already produced for the world market for textile use.

An analogous situation in the paper industry to the commercial development of the kenaf crop for textile fiber in the United States was reported by Atchison (9). In discussing, in 1969, the desirability of separately pulping the two types of component fibers of the kenaf stalk and the possibilities for using them for different grades of pulp, it was pointed out that the use of bagasse for papermaking was held back for 50 years because all efforts to use it involved the use of the whole bagasse without separation of pith. This was in spite of the fact that it had been known and patented for many years that in order to obtain a good quality of pulp it was necessary to remove the pith before pulping the bagasse fiber. All of the early mills built to use whole bagasse failed and it was not until the bagasse fiber and pith were separated before pulping the fiber that this raw material was used successfully and the mills could continue to operate and market their products.

It was on the basis of this experience with bagasse and their familiarity with the technical advantages of pulping separately the bast fibers of nonwood plant fibers that has caused the Consultants to point out in publications (3) the advantages of the use of kenaf bast ribbon pulp as a possible replacement for high strength softwood pulp. At the same time, it was recognized that kenaf whole stalk chemical pulp can be used in certain paper furnishes and that the woody core material has characteristics favorable for its use in manufacturing mechanical pulp for newsprint and groundwood containing type printing and writing papers and also for semichemical pulps for corrugating medium. It has also been suggested that removal of some of the fine, nonfibrous material in the woody core component before pulping the kenaf whole stalk in an operation similar to that for depithing bagasse would result in improved chemical whole stalk pulp properties. Other uses of the separated core material suggested were for particleboard, medium density fiberboard, and for the manufacture of charcoal and chemicals such as furfural or xylitol. The fuel value of the woody core has also been recognized because a metric ton of this material at 50 percent moisture content, when burned in a modern refuse burning boiler, should produce as much steam as 1.0 barrel of fuel oil. If woody core material (or even whole stalk kenaf) at field dry condition of 12.5 percent moisture were available, a metric ton of it would generate as much steam as 2.35 barrels of oil.

2.2. Harvesting the Bast Fiber in Kenaf for Paper Pulp

The historical, traditional procedures for the hand harvesting, retting and preparation of kenaf and other bast fibers for textile and cordage usage are well known. It is very important that they be considered for the production of the kenaf raw materials for a pulp mill wherever agricultural labor is plentiful and its cost low, as in the Mekong Basin area. This portion of the subject, relating to the whole stalk harvesting or the separation by hand of the kenaf bark for paper pulp, will be covered in the agro-economic sections of this Study.

The cleaned or retted bast fiber produced for textile purposes by the farmer has been freed of a considerable amount of fine particles and incrusting water soluble organic materials, thereby improving the pulping qualities of the fiber even in comparison to those of the kenaf bast ribbon without wet cleaning. The fibrous raw material for pulping in this form can be cooked directly without any preceeding wet cleaning treatment and with minimum chemical consumption to yield pulp of the maximum strength and drainage properties that can be made from that component of the kenaf.

However, the laborious and unpleasant step, which requires the farmer to ret the kenaf stalk, is not economically desirable for the fiber for the pulp mill because its cost is appreciable in proportion to other costs of producing the fibrous raw material. It is also not necessary because the same results, from the pulping standpoint, can be achieved on the bast ribbon with the fiber cleaning system used at the pulp mill, thereby giving the kenaf farmer more time to spend on other agricultural activities to increase his productivity and income. It has been estimated, as shown later in the agro-economic sections in this Study, that eliminating the retting step for the kenaf saves 30 to 35 percent of the farmer's cost-effort investment in supplying the kenaf bast fiber to the pulp mill in just as acceptable a form as ribbon rather than as retted fiber.

In supplying the field dried whole stalk, which eliminates the manual stripping or mechanical ribboning step, the farmer's time and labor savings would be increased even more for a given amount of kenaf crop supplied to the pulp mill.

In searching for additional published information on the harvesting of the bast component of kenaf for paper pulp, the Consultants find that there is a tremendous amount of literature on the decortication of the hard (or leaf) fibers such as sisal, abaca, and henequen, and the decortication or ribboning of the soft (or bast) fibers such as

jute, hemp, ramie, and kenaf. Byrom (13) reported that, by 1956, the files of the United States Patent Office alone showed some 2,000 decortivating machines and processes had been invented or patented. He pointed out that the term "decorticated fiber" is bast fiber from which the woody portion of the stem and the outer bark have been removed in the so-called raspador unit so that only the fiber embedding gums and organic binders are left behind with the fiber, to be solubilized and removed by retting.

In contrast, as Byrom (13) defined it, the term "ribbon" refers to strips of the bast layer removed by hand or mechanical means. This includes all the cortical tissue as well as the gums and may contain a small amount of the woody core material. For paper pulp purposes, only the ribbon form of the bast fiber will be considered in this Study in subsequent sections.

It is interesting to note that, 10 years later, Allison (14) stated that even for textile fiber production the research and engineering work on mechanized kenaf bast fiber production was only well begun. Because it was found to be not economically feasible under conditions in the United States to process crude ribbons from kenaf by natural retting, he stressed the need for developing a field harvester to "decorticate" the stems rather than producing the crude ribbon for textile use.

By 1970, Allison and Boots (15) published the following comment outlining the requirements they envisioned for mechanized harvesting of kenaf for its bast fiber:

The main objective is, of course, to describe, even in a very general sort of way, a proposed field harvester-decorticator for these two crops [ramie and kenaf] which, in a single pass across the field, will do three things, namely: a) deliver the tops or waste of either for dehydration and subsequent use as a high-protein feed for poultry and livestock, b) harvest and decorticate the stems and deliver the fiber either in full length hanks or stapled at some predetermined length, if preferred, for economy of handling in all subsequent operations, and c) save the wood and fiber waste from the decortication process either in whole or some preferred part for use as paper and spreading the undesired part if any, or the whole, evenly over the land as the harvest progresses.

They also outlined their conception of the design for the decortication section of such a machine. This was based upon the earlier design of Friedrich Mertz at the Krupp plant in Germany which had resulted in the building, by Sea Island Mills, Inc. in Florida, of a ponderous machine, weighing about 18 tons, for field trials on harvesting ramie in the early 1950's. They reported that this machine did not operate efficiently and economically due to its extreme weight and poor maneuverability. However, they claimed the decortication system worked quite satisfactorily when the plant stems were presented to it in a proper manner.

It is interesting to note that Allison (16) has recently indicated that an experimental prototype of the "3-Way" harvester has not been built due to lack of financing rather than questions as to its potential success. This is over 20 years after the report of Whittemore and Cocke (17) on the mechanization of kenaf fiber production stated that a new combination cutting and ribboning machine designed by the USDA was under construction.

It is quite apparent, from this information and the Consultants' knowledge of what has actually happened in the field as a result of the ill fated attempts by the USDA and others to build and operate these complicated combined harvesting and decortication machines for kenaf, that they have not been successful, to say the least. However, this has not been the case with the basic, hand fed, mechanical ribboning machines which are being successfully used on kenaf in actual commercial operations for textile purposes. These latter units would serve very well in moderate cost labor areas to separate the kenaf bast ribbon for paper pulp.

Certainly the efforts to develop new machines and techniques for separating the bast ribbon of kenaf from the core material are by no means ended. The Toyo Pulp Co. in Japan has developed a machine with an automatic feeding mechanism for ribboning bast fiber plants. Hanaya (77) has reported it is successful but the details of the equipment have not been published. In Australia, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) has developed a system for separating kenaf bast ribbon from the woody core material and this might eventually be modified for use in mechanized harvesting of the bast material. As described by Watson, Davies, and Gartside (78), a patent on the process has been applied for in conjunction with the extraction of the juices from green kenaf by crushing the stalk, after deleafing, in a sugar cane roll press. The two fractions of the stem are separated by screening and this is possible because the bast ribbon

comes from the rollers as a stringy fibrous mass and the woody core is in particulate form.

The fact that there have been these previously mentioned equipment failures for the combination harvesting and bast raw material separating machines does not eliminate the need for their eventual development for use in high labor cost countries where kenaf ribbon might be needed and could be grown for textile fiber purposes or for pulping to produce a substitute for softwood pulp.

In fact, the Consultants are well aware of the recently developed systems and equipment for mechanized harvesting and handling of sugar cane that, with proper modification, could be used for kenaf whole stalk and ribbon where grown on large plantations. These sophisticated units have been built by agricultural machinery manufacturers for use all over the world and hundreds have been sold in the last five years and are in successful operation. When and if there is an appreciable market for suitable units for use on kenaf, they will undoubtedly be quickly developed by the equipment manufacturers by modifying the sugar cane equipment.

This statement is made based on the Consultants' recognition of the fact that field mechanization of kenaf production would only be economical for large tracts of land and where agricultural labor would be expensive. For the kenaf paper pulp development in the Mekong Basin area under the prevailing farming situation, any detailed review of the information on mechanized cane harvesting that might be applicable to kenaf is unwarranted for this Study.

2.3. Harvesting Whole Stalk Kenaf for Paper Pulp

The traditional hand harvesting procedures used in the Mekong Basin area for preparing bundles of mature green kenaf stalks ready to be transported to the retting facilities have been described in the agro-economic sections of this Study. The same procedures could also be used for harvesting field dry standing stalks of kenaf. For the Mekong Basin area with its low cost agricultural labor, and particularly where each farmer and his family grow only small plantings of kenaf, this system appears to be far more economically and socially desirable for the foreseeable future than trying to use large scale mechanical harvesting equipment for the supply of whole stalk kenaf to the pulp mill. This would be the case particularly when the farmer is relieved of the burden of the laborious retting step that he now carries out on the bast fiber for the textile mill.

However, when the major studies for using whole stalk kenaf in the United States for paper pulp were begun by the USDA in the early 1960's, it was already obvious that large scale crop production near the pulp plant and mechanized harvesting would be required. In an economic analysis of the growing of whole stalk kenaf for paper pulp, Trotter (18) estimated cutting and binding costs based on the use of a modified grain binder for the stalks similar to that used in harvesting hemp for cordage fiber. It should be noted that this system for cutting and binding hemp on large tracts during World War II was previously used for harvesting ramie whole stalks according to Byrom (13). Later, Trotter and Corkern (19), at the First Conference on Kenaf for Pulp in 1967, repeated the economic analysis of kenaf cost in comparison with other crops based on the use of forage harvesting equipment and suggested lower harvesting costs could result with large contractor operated equipment or with units supplied from the pulp mill.

Other reports by Uhr (20) and Guttery (21) at the Kenaf Conference of 1967 discussed the experience in harvesting at Hudson Pulp and Paper Company's trial kenaf plantings where a conventional forage harvester with collection trailer and with corn head pickup was used. The operation was not completely satisfactory and the need for a better topping device for the stalks, growing as high as six meters, was recommended.

As an additional step in harvesting, the Kenaf Conference of 1967 considered the possibilities for dewatering the chopped kenaf. Casselman (22) from the Everglades Experiment Station in Florida discussed the use of screw presses to dewater various forage chopped crops to allow economic thermal dehydration. Clark (23) of the NRRL mentioned

studies on pressing the kenaf with two types of screw presses or a sugar cane roll press to decrease the cost of transporting green kenaf and preserving it in storage.

At the same Kenaf Conference in 1967, Wilkes and Whiteley (24) reported on work over an eight year period at the Texas Agricultural Experiment Station on the harvesting and handling of kenaf. Their studies covered the machine operating capacities and efficiencies and costs for harvesting with forage harvesters, a flail chopper, cutter-crimper, baler, binder, and an experimental saw to cut the stalks.

A later and more comprehensive report by Wilkes, Hobgood, and Whiteley (25) from the same experiment station is reviewed in detail in the agro-economic section of this report. In this extensive study the kenaf stalks were either chopped, chopped and baled, whole-stalk baled or saw cut.

The research at that time showed that kenaf could be harvested at lowest cost with a conventional forage harvester in chopped form at a density of 76 kg./cu.m. for about 15 percent of the cost of harvesting an equivalent unit of wood. The baler system harvesting cost was one third the cost of harvesting an equivalent unit of wood, but the commercial equipment used for the trials had several limiting factors. It required kenaf with a maximum stalk height of 1.8 m. and a maximum stem diameter of below 1 cm.

Moisture content at time of baling field dried chopped kenaf was below 20 percent. The principal advantage of field baling was the bulk density of 135 kg./cu.m. favorable for reducing transportation and storage costs. Whole stalk bundle harvesting resulted in a total cost of harvesting of about 85 percent the cost for an equivalent weight of dry wood. Drawbacks of this system were low capacity, excessive labor requirements, and low density of bundles at 45 kg./cu.m. It should be pointed out that the cost data given in this report are so far out of date that to discuss them in this review would be greatly misleading.

Conclusions by scientists of the USDA on the mechanical harvesting of whole stalk kenaf for paper pulp were outlined, in 1970, by White, Adamson, and Higgins (26). They stated that, in the United States, all harvesting and subsequent handling of kenaf to the mill would have to be completely mechanized to be economical and practical. The most suitable harvesting system found was to chop the standing crop, either green or in field dry (crop killed by frost or chemicals) condition. Choppers with reel or cylinder type cutting action were found to be more satisfactory than flywheel types. It was also found that row headers

could handle the tall stalks better than cutter bar headers. Removal of the kenaf leafy top portion by a mechanical topping machine for forage or a defoliating spray was said to be desirable for a green chopped product. The high nitrogen (protein) content of the leaves makes them suitable for animal feeding or building up the soil. In addition, the yield and quality of pulp from the leafy tops are quite low compared to those from the major part of the stalk.

Much of this same information has been reviewed by White and coauthors (12). They reported that, in general, flail choppers and binders have been unsatisfactory and that regular farm balers will not satisfactorily bale finely chopped kenaf or pick up windrowed kenaf unless it has been crushed by a cutter-crimper. Although resultant leaf losses would be desirable from cutting and windrowing the kenaf crop, this method of harvesting introduces dirt, decreases the quality and increases the losses due to spoilage and bad weather. It was noted that whole stalk material fed into a baler by hand gave bales of a density approximating 178 kg./cu.m. (OD basis).

Although the methods of harvesting whole stalk kenaf were not described, Moore and coworkers (27) of the USDA have recently estimated the costs for harvesting kenaf in a comparison with the cost of producing the other major agricultural crops of corn, cotton, and soybeans, and pine pulpwood in the Southern United States. Of the total cost of US\$68/ha. budgeted for harvesting and hauling 11 tons/ha. of oven dry equivalent solids as green kenaf stalk to the pulp mill, it was estimated that US\$31/ha. (US\$2.82/ton) or 45 percent was the harvesting cost.

At the present time, work on breeding, production and harvesting of both H. sabdariffa and H. cannabinus is being continued in the Southern United States by the USDA. Their latest report (28), early in 1975, recognized that field chopping with forage harvesters, especially for the field dried stalks, requires a heavy expenditure of energy. Although the green material is more easily chopped, it was considered that the storage and handling systems available for green kenaf appear to be too expensive to use. It was also believed that a mechanical harvesting system that would handle small stalks in densely planted stands would be desirable because close planting maximizes yield and probably bast fiber percentage. The present objective outlined for research for the USDA is to develop an economical and efficient mechanized system for harvesting, handling and storing kenaf for paper pulp. The proposed research approaches include developing machinery to harvest whole stalks of kenaf and to modify existing chopping and forage handling systems for use with kenaf.

From the foregoing it would appear that the harvesting of kenaf as whole stalks, as is traditionally done by hand in the Mekong Basin area, is coming back for serious consideration and study even in the United States, although on a mechanized basis. It is also apparent that, eventually, these studies will have to include tests on kenaf with the highly sophisticated designs of sugar cane harvesting equipment as has already been done in Queensland, Australia, or with new kenaf harvesting equipment designed along similar lines.

2.4. Transporting Whole Stalk Kenaf for Paper Pulp

Very little has been published on the transportation of kenaf in any form to a pulp mill. For the limited mill scale trials at Hudson Pulp and Paper Company in Florida in 1965, Guttry (21) reported that the green chopped kenaf was hauled to the mill in field wagons holding 3.6 tons and also in dump trucks carrying 1.8 to 2.3 tons. This was, of course, done as a matter of expediency and for lack of anything more suitable. In discussing this particular trial, Uhr (29,30) concluded that because of the low bulk density of 81 to 129 kg./cu.m. (OD basis) of forage harvested and chopped bagasse as compared to 323 to 485 kg./cu.m. for round pulpwood and 162 to 242 kg./cu.m. for wood chips, economical transportation of kenaf in Florida would be limited to a radius of less than 48 km. to the mill. Actually, the situation would have been even more unfavorable if it had been considered that the green kenaf contains about 80 percent moisture whereas wood contains only 50 percent moisture on the average when harvested.

In their study of forage harvesting of green kenaf, Trotter and Corkern (19) assumed that 2.3 ton trucks and an average hauling distance of 32 km. would be used. The use of such a small truck would obviously result in high costs for transportation of raw materials.

In an update of their economic studies of kenaf production, scientists and economists of the USDA (27) have estimated that, of a total cost of US\$68/ha. in the budget for harvesting and hauling 11 tons/ha. of oven dry equivalent solids as green kenaf stalks, US\$37/ha. (US\$3.36/ton) or 55 percent of the combined cost was for transportation to the pulp mill from the field. A recent study has been made on the economics of transporting chopped sugar cane to the mill that will be of interest for future studies on transporting kenaf. Cochran and Whitney (31) have used a computer to develop a model from field data to predict the delivery rate of cane to the mill for a given transport system and to optimize the system based on cost of delivery for a ton of cane.

For kenaf whole stalk transport the Eastern Paper Mills Corp.(32) in Sri Lanka has used open lorries for hand tied bundles of field dried stalks. The transportation of such low density material in trucks for any distance would be very costly and providing an adequate supply of kenaf to a large pulp mill by this means will have to be carefully studied and planned from the logistical standpoint as is being done in the agro-economic sections of this Study.

In cases where kenaf would be grown on large plantations, consideration and further study must be given to the transportation systems used in the fields and on the highways by the cane sugar mills for whole or cut stalks. Such systems have been under development for many years by the cane sugar growers and equipment manufacturers all over the world as well as by U.S. industry groups, such as the Sugar Cane Growers Cooperative, and Government agencies such as the USDA.

There are several successful designs of sugar cane transport systems in use. One of the most recent components to come into use is the infield transporter Hi-Lift, a self-propelled four-wheel-drive unit which carries a large box for receiving the cane cut by the harvester into short lengths. This box can be elevated when filled and tipped over to dump the cane into large cane haul trailers, some of which are capable of carrying as much as 40 tons of cane over soft fields. These cane haul trailers are then pulled by a truck or tractor (or a locomotive, if transport is by rail) to the sugar mill. There the load is weighed and then unloaded by tilting either the box on the trailer or the entire trailer.

Therefore, it can be assumed that mechanical equipment for harvesting and transporting kenaf either in whole stalk or chopped form on large plantations has already been developed by the sugar industry and can be applied to kenaf when the necessity arrives. Very little, if any modification of present design of equipment is expected to be necessary for this crop.

However, it does not appear that such systems can be applied where the kenaf is produced on small farms such as in the Mekong Basin area. Here, it can be expected that a traditional transport system will be used due to the plentiful and low cost labor available. In this system's most elemental form, the bundles of field dried kenaf stalks or bast ribbon will be carried from the farm by bullock cart to the nearby pulp mill for processing or to local collection centers for baling and eventually hauling to the pulp mill by truck.

2.5. The Storage of Kenaf for Paper Pulp

2.5.1. Introduction

Kenaf, an annual plant, has an advantage in that supporting infrastructure and a crop can be developed on bare arable land to supply a paper pulp mill with inadequate wood supplies within a year or so where, otherwise, it would require at least a generation to establish and grow the first part of a forest plantation to reach maturity before the mill could be built. However, because kenaf is an annual crop that would be harvested during a period extending for three or four months beyond the time of maturity or frost kill, storage of a year around supply of the whole stalk material for the pulp mill presents a very serious problem.

Where there is year around harvesting as in the case for trees, most of the supply of the cellulose for the pulp mill can be "stored on the stump" for indefinite periods of time and provide a continuous financial return in the form of growth increment of fibrous raw material while "in storage".

Kenaf for a pulp mill, on the other hand, would in most localities require storage for up to 8 months of the year. Therefore, preservation in storage in some form that will maintain uniform pulp strength properties and prevent costly loss in yield or gain in pulping and bleaching expenses is required. Preservation of desired properties is, of course, desirable at the lowest cost for storage and handling.

Uhr (29) has estimated that chopped green kenaf required to support a year around 91 tons per day small pulp mill would require a storage pile covering nearly 6 ha. to a depth of 12 m., as if this were something unusual. This would, of course, represent the maximum inventory at the end of the harvest period and would be no different from storing bagasse for a mill of equivalent capacity, where the cane grinding season lasts three or four months out of the year.

Fortunately, the storage of nonwood plant fibers in either wet or dry form for pulp mills is not new in the industry. Actually, at the First Kenaf Pulp Conference in 1967, it was suggested by Atchison (9) that bulk storage of kenaf would improve its properties for paper pulp. This was based on results achieved on bagasse where storage improved the drainage rate in pulp washing and reduced the foaming.

For many years, straw and bagasse both have been baled and stored in covered ricks for pulp mills and bagasse has also been stored in both wet and dry bulk form for the entire season between crops. Because kenaf contains sugars and other water soluble organics and gums as do bagasse and corn silage, it is only logical to conclude that silage storage systems and, preferably, the systems of bale and bulk storage described by Atchison (33,34,35) and more recently developed wet storage systems for bagasse, can be used for the storage of kenaf collected by mechanized harvesting on large farms. It should be emphasized that, in their extensive work done on the storage of kenaf recently, the scientists of the USDA have begun to take these factors into consideration in an attempt to duplicate the successful results which have already been achieved in storing bagasse.

In addition to the various methods that could be used for storing kenaf in bulk or bales after it has been harvested, there has been serious consideration given to storing the whole stalks for a period of several months by leaving them standing in the field after maturity. This would also facilitate harvesting by extending it over a longer time period and thereby make possible a longer time use each season of any equipment involved, the labor employed, etc., as explained in the agro-economic chapters of this Study.

In the temperate zone, this field storage time would start when the kenaf is killed by frost and in tropical climates when it flowers, goes to seed and matures due to photoperiodism, which is the plant's reaction to the reduced hours of daylight at the end of the growing season.

Whiteley (36) noted that harvesting delayed after frost resulted in significantly reduced yields of dry kenaf solids per hectare. Higgins and White (37) found for kenaf plantings in Maryland, U.S.A., that the highest stem weight yield was when the harvest was made immediately before or after frost. They found stem weight yield gradually reduced with delayed harvest after frost because of loss of plants by lodging.

Because of the agronomists and other scientists of the USDA have been studying the losses of fiber for pulp and other solids in the stalk when kenaf is stored under different conditions, it is logical that they have now begun to investigate the losses and changes that occur when the stalks are left to stand in the field for several months after the plant matures or is killed by frost. There had been a recognition, in 1970, by White and coworkers (12) that there was a discoloration of stalks that remain in the field while drying for a

prolonged time before harvest. It was also reported that this discoloration resulted in the appearance of spots or specks in the pulp. However, others have not reported this phenomenon.

Recently, an investigation has been made by the USDA researchers to determine the stem yield of dry matter and the chemical composition of these solids from kenaf harvested about six weeks before frost, immediately after frost and at subsequent monthly intervals. Bagby, Adamson, Clark, and White (38) have reported their findings that, during successive monthly harvests over a three to four month period following frost, the extractable solids content of the stalks declined whereas the cellulose, pentosan, and lignin percentages increased. Although a decrease in yield of total solids in the kenaf stem took place after the frost, the crude cellulose solids ratio increased. Therefore, the yield of cellulose at the fifth harvest remained at least equivalent to that from the first harvest of green kenaf about 1.5 months prior to the frost. It was concluded in this study that, barring any untoward lodging problems, it would be feasible to extend kenaf harvests for at least two months after frost without sacrificing any of the papermaking cellulose yield for a given area of land.

Therefore, on the basis of this information, it appears that field drying of the kenaf, at least in the United States, during a reasonably prolonged storage period before harvesting while the leaching of soluble solids from the stalk by rain takes place, certainly does not have a deleterious effect upon the pulping characteristics and final yield of cellulose for pulp. In fact, on the basis of the evidence, it appears this system of field drying could find practical and economical application in the baling and storage of kenaf for a paper pulp operation in the Mekong Basin. The loss of soluble solids from the stalk while standing in the field to dry would not only aid in the cleaning of the fibrous raw material before pulping but would also significantly reduce the load on the pollution control system resulting from the wet cleaning of the kenaf before the pulp mill digester.

2.5.2. Bulk Storage of Kenaf

Clark (39) reported to the First Conference on Kenaf for Pulp that the USDA had made a preliminary laboratory study, in 1965, of the effect of anaerobic storage of green kenaf on the quality of bleachable sulfate pulps made therefrom. In the first test, satisfactory pulp was produced after a storage time of two months under these conditions for preservation and followed by a wet precleaning of the ensilaged chopped green stalk before pulping it. A second test, in 1966, on whole green stalks and frost killed stalks after storage as ensilage for four months also gave satisfactory pulps.

At the same Kenaf Conference, according to Atchison (3), Uhr described the bulk storage system used by Hudson Pulp and Paper Company for successfully preserving chopped green kenaf. They used bunker type silage storage in piles of 1,000 tons (OD basis) which had been compacted with a bulldozer. Molasses had been added to the kenaf to promote ensilage. It was pointed out that this system was somewhat similar to the Ritter wet storage process for bagasse where a lactobiological culture solution plus molasses is used when hydraulically piling the raw fiber into a compacted pile for storage.

Some general information on bulk storage of kenaf was reported by Wilkes, Hobgood, and Whiteley (25). The temperature of the material, its color, and general appearance along with results of pulping tests were used as indicators of the storage characteristics of kenaf stored in bulk form. They found the moisture content at time of storage a limiting factor but the size of the storage pile was said to have no apparent influence on the storage. Temperature rise was found to be a good indicator for detecting deterioration of kenaf stored in chopped form. All kenaf stored in chopped form above 35 percent moisture content discolored and decayed with increases in temperature of the piles and the deterioration increased with increased moisture content. Chopped kenaf stored below 35 percent moisture remained essentially unchanged and when stored outside there was only a 5 to 8 cm. thick layer of discolored material on the outside of the pile. In the case of bulk stored pieces of kenaf stalk that had been saw cut to 0.3 m. lengths, no deterioration was found for as high as 52 percent moisture content when put into storage.

By 1970, White, Adamson, and Higgins (26) and White and coworkers (12) of the USDA pointed out that, for chopped green kenaf, the leafy top portion should be first removed. At moisture levels above 30 to 35 percent, the possibilities suggested for preserving green chopped kenaf included that it be:

- (a) stored like corn silage in pit, trench, or bunker silo;
- (b) submerged in water until processed;
- (c) stored in sealed and air evacuated enclosures (cocoons) of plastic sheeting;
- (d) dried artificially to a safe moisture level, and stored in covered piles or bins; and
- (e) stored in open piles, with or without continuous or intermittent spraying with water.

White et.al. (12) pointed out that the first three techniques preserve the kenaf under anaerobic conditions and that cocoon storage in plastic coverings has previously been studied for preservation of pulpwood and chips and green forage. The artificial drying was recognized as being economically prohibitive. Storage in open piles was considered to be unsatisfactory unless there was controlled application of water such as has been used successfully for pulpwood and bagasse preservation.

From the above, it becomes apparent that, for a large scale supply of kenaf from a plantation to a pulp mill, some variation of a bulk wet storage and handling system at the mill for green or even field dried chopped kenaf might be the most practical and produce the cleanest raw material for pulping. This would be somewhat comparable in ease of operation and fibrous raw material preservation efficiency to the Ritter system which has proved to be successful on bagasse. It would appear to be one of the logical choices of a bulk storage system to be further investigated.

The first detailed technical study of the effect of various storage methods on both field dried and green kenaf stalk on the resultant pulp properties was reported in 1970 by Clark and coworkers (40). The study on shredded green stalk storage was based on conditions approximating ensilage of kenaf at 77 percent moisture content in pilot plant silos. As the kenaf stalk had a sugar content of about 6 percent, which is equivalent to the highest value for residual sugar in bagasse, the glucose under anaerobic conditions was converted to lactic acid during fermentation rather than the acetic acid which results from fermentation under aerobic conditions. This build-up of lactic acid retarded microbial attack on the cellulose and pentosan fractions of kenaf, the same as it does for bagasse stored by the Ritter process. Pulping tests were made on shredded green stalks with tops before and after ensiling for 500 days with acid treatment. Shredded green stalks without foliage were also pulped before and after ensiling under various conditions for different storage times extending up to 500 days. Some of the ensilaged samples were originally treated with acid or molasses.

An additional trial was made on chopped green kenaf that had been completely immersed in water for 100 days. A comparison test to this was also made on another sample of chopped green kenaf kept in a perforated container and dipped in water, with the water drained off, once a day for five days out of every seven days for the 100 day period. This latter procedure was designed for alternate wetting and air infiltration into the wet kenaf.

These trials produced some very interesting results beyond merely a preservative action on the kenaf under anaerobic conditions. They also showed that when the ensilages were washed with 15 to 20 percent of the equivalent dry solids being removed as water solubles or fiber fines before pulping, improvements in the pulps produced resulted from ensiling and washing regardless of the treatment at ensiling time. The presence of kenaf stalk foliage in the ensilage was found to have an adverse effect upon yield, the strength index and the drainage rate of the pulp. It was estimated that, if chopped green kenaf were stored in a trench or bunker silo of 9 m. depth, the top 0.3 m. layer, or about 3.5 percent of the total kenaf stored, would be contaminated and deteriorated from mold growth. The daily immersion of chopped green stalks in water and draining, which would simulate rainfall or intermittent spraying in bulk storage (actually without maximum compaction and preservation of high moisture content for maintaining anaerobic conditions in the pile), did not preserve the lignocellulosic material as well as ensilage or produce a pulp equal in quality. However, total immersion achieved the maximum preservation of lignocelluloses, promoted the removal of pith, and resulted in removal of undesirable water soluble materials.

An initial economic appraisal was also made to compare the various storage techniques for green kenaf against the storage of baled field dried stalks. Based on the losses resulting from storage, the chemical cost for pulping, and the final yield of pulp, storage of chopped green kenaf by continuous immersion was almost as low for material cost as for field dried whole stalks stored in covered ricks. Costs for materials for kenaf stored as ensilage were somewhat higher than for rick storage or water immersion storage. However, the comparison made is not really valid because the complete comparative costs of harvesting and transporting the kenaf to the mill, the investment for storage and fiber reclaiming and cleaning facilities, and the labor, etc. required for the different processes have not been taken into consideration. Each mill at a different location, in developed or developing nations, would present different cost patterns for the kenaf supply, depending upon the many variable factors not evaluated in this study by the USDA.

Therefore, the chief value of the study was to show, from the technical standpoint, that whole stalk kenaf can be stored successfully for a pulp mill as field dried whole stalks in bales or in green form as shredded ensilage or as chopped pieces immersed in water.

A more recent investigation by Bagby, Clark, and Cunningham (41) of the USDA has covered the pulping of wet processed stored green kenaf. Both dejuiced foliated and defoliated green kenaf and its separated bast ribbon and woody core material were stored for nine months anaerobically either as is, under nitrogen, or in the presence of propionic acid or borax. The basic scheme of sample treatment for preservation, although not used in all instances, was as follows:

Unstored		Stored			
		Chemical Treatment			
		Nitrogen	Borax	Propionic Acid	
Uncleaned	Wet Cleaned				
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After storage, the preserved solids of the various samples were wet cleaned and chemical analyses and pulping and bleaching trials were carried out for comparison with the original samples before any treatments. The investigators, in general, found that recovery of the cleaned residues ranged from 52 to 73 percent of the original solids in the kenaf sample, with no completely consistent trends discernible. However, the data given, if studied carefully and interpreted for their practical significance, can be applied to the design of raw material requirements for a pulp mill operating on a whole stalk green kenaf supply. This is the first study that allows a realistic estimate of the yields of finished bleached pulp that could be anticipated to result from the whole stalk kenaf or bast ribbon or woody core material, harvested at maturity while still green, both before and after storage under anaerobic conditions for nine months.

In one example, when shredded green kenaf stalk material with included foliage, and after dejuicing but before storage, was wet cleaned, the cleaned residue was 73 percent of the original solids in

the untreated sample after dejuicing. It must be realized that an additional amount of solids was lost in the dejuicing before wet cleaning. Storage of the sample as was or with propionic acid or borax followed by wet cleaning reduced the cleaned residue recovery to 53 to 65 percent. Wet cleaning of the samples before storage reduced the chemical consumption in pulping and bleaching. Storage followed by wet cleaning also gave a further reduction in pulping chemical requirements. It would appear that, in general, the bleached pulp yield (OD basis) that was obtained in their work from the original green whole stalk kenaf as harvested averaged about 30 percent, or slightly higher, at optimum pulping and bleaching conditions both before and after storage.

In the case of kenaf bast ribbons, storage had a very beneficial effect in improving the pulping characteristics. Their bleached pulp yield was about 40 percent of the original solids in ribbon stripped from the green kenaf stalk.

The benefits of storage and cleaning also extended to the manufacture of pulp from the woody core material in their tests. However, under the standardized test condition used in this investigation, optimum pulping and bleaching conditions were not attained for this raw material. It appears that bleached chemical pulp yields prepared under optimum conditions would be in the range of 23 to 27 percent of the total dry solids originally present in the green woody core material.

One of the basic and very important conclusions of this study was that wet cleaning tended to equalize the chemical compositions of materials recovered from foliated and defoliated whole stalk kenaf, regardless of storage history. Compared with the original green materials by chemical analysis, the cleaned residues, and particularly those recovered from storage, contained 20 to 40 percent more cellulose, pentosan, and lignin combined and a correspondingly lower total of extractives, nitrogen (protein) and ash. These favorable factors result in improving the pulping characteristics of the kenaf and its fractions as well as lower the chemical consumption for pulping and bleaching.

Based on these excellent studies by the USDA, it appears that an optimum system for bulk storage and preservation of green or field dried kenaf is very near to becoming developed for commercial use by a large pulp mill. Any further studies on wet bulk storage of kenaf should start at duplicating the Ritter process which has been used for some years for storing bagasse successfully between harvests.

Again, however, the Consultants want to emphasize, and as will be discussed later in other sections of this Study, that a system of bulk storage of loose kenaf in either wet or dry condition would not appear to be the best choice for the Mekong Basin project mill.

2.5.3. Storage of Baled or Bundled Kenaf

Storage of baled nonwood plant fibers such as straw, esparto, and bagasse at pulp mills was the first method commercially used. Atchison (33,34,35) has reviewed in detail the bale storage methods in use around the world for bagasse baled at approximately 50 percent moisture content. These are the Celotex method, the system for mechanical handling of baled bagasse developed by the South Coast Corporation and the Thibodaux Boiler Works, the Taiwan method for storing and handling small bales, and the use of large bales. It will be very important in developing bale storage systems for kenaf that these systems be given consideration.

At the First Conference for Pulp, Cummins (42) mentioned tentative observations by scientists of the USDA on the effect of storage on the chemical composition of kenaf stalks baled at an initial moisture content of 20 percent. It appeared there was a loss of cellulose with time and the effect of leaching of solubles from the kenaf in uncovered stacks was observed.

Some general details on storage of kenaf in bales or bundles have been given by Wilkes, Hobgood, and Whiteley (25). The temperature of the stored material, its color and general appearance along with results of pulping tests were used as indicators of the storage characteristics of kenaf. The storage of kenaf in chopped form above 35 percent moisture content resulted in temperature increases, discoloration, and eventually the kenaf decayed. The rate of deterioration increased as the moisture content increased but chopped kenaf stored below 35 percent moisture remained essentially unchanged. Since only a layer of 5 to 8 cm. thickness on the outer surface showed signs of discoloration and deterioration, outside storage of kenaf in chopped form was said to be feasible.

The maximum safe moisture levels for kenaf storage in bundles and saw-cut lengths were not clearly established. Saw-cut kenaf was stored at moisture levels as high as 52 percent without quality changes but decay and mold growth were observed in stacks of bundles with moisture levels above 62 percent. There was no deterioration of the kenaf in

bale storage as the moisture was below 20 percent. It was claimed that the size of the stacks had no apparent influence on the storage results.

The first detailed report of technical data on the effect of storage of field dried stalks of kenaf in bales was by Clark and coworkers (40). Their study compared the results of this method of storage on the chemical analysis of kenaf and the pulp that was produced with the results of similar tests on green kenaf which had been stored as ensilage. It was pointed out that, although field storage of kenaf as standing stalks might be an economical and satisfactory way to store raw material for several weeks' operation of a pulp mill, it might interfere with optimal land use and permit stalks to lodge so that mechanical harvest would be more difficult and result in losses of stalks.

In this investigation by the USDA, it was demonstrated that variable losses of the stalk components occurred with different degrees of protection of the bales of frost killed field dried kenaf when stored in Georgia for periods up to 18 months. The kenaf stalks were baled at approximately 25 percent moisture content. Two small ricks of bales were set up and one of them was left uncovered with the other having a cover over only the top tier of bales. Comparison bales for testing were stored in an unheated dry barn. The study showed that baled field dried stalks, stored in a covered rick for 18 months, lost only 1.6 percent of the original solids in the interior bales but none from the top or exterior bales. It was believed this loss resulted from enzymic and microbial activity encouraged by the initial moisture content of 25 percent being retained in the interior bales for awhile due to the covering. There was no loss of solids from bales stored in the barn but it was reported that for the uncovered rick the top bales lost 50 percent of the original solids, the interior bales lost 30 percent and the exterior bales on the sides lost 19 percent. Chemical analysis indicated only slight changes in composition of the kenaf stalks when in protected storage. Pulping tests showed that unbleached pulp from bales stored in a covered rick had physical strength characteristics equal to the original material or bales stored indoors. However, the pulp yield was slightly lower for the bales in covered ricks. In the case of bales stored in the uncovered rick, the pulp yield was reasonable when based on the material fed to the digester. However, when based on the original stalk weight as baled, the yield was very much lower than bales stored covered or in a barn. In addition, the strength properties of pulp from bales in uncovered ricks, particularly on the exposed top layer, were much lower than pulps from properly preserved fibrous raw material.

Making a calculation, based on recovery of solids from storage and chemical consumption for cooking, for estimated material cost resulting from the different systems of storage tested, these investigators showed that covered rick storage of bales would cost less and result in a lower consumption of fibrous raw material to produce a given amount of pulp than wet bulk storage or ensiling of green kenaf. It should be pointed out that this cost data comparison is not valid for the reasons given in Section 2.5.2. of this Chapter I on the bulk storage of green kenaf. Also, this calculation did not consider or compensate for the losses of solids from the stalk due to rain leaching, fermentation of sugars, and other changes during the period of field drying. Therefore, any comparative consideration of final yields of pulp resulting from the different storage methods has to keep these factors in view at all times.

There has been some concern about the discoloration of stalks that remain in the field for a time drying after being frost killed. According to White and coworkers (12), this discoloration results in the appearance of spots or specks in the pulp. It is not known at this time whether or not these spots form on field dried kenaf in a climate free of frost.

Very recently Bagby, Cunningham and Clark (43) of the USDA published data on the effect of long-term bale storage conditions and moisture content on comparative pulp yields and physical strength properties of bleached soda and sulfate pulps from field dried whole stalk kenaf. Parallel tests were also run on green kenaf that had been dejuiced or artificially dried before pulping.

In this investigation, frost killed stalks were allowed to field dry to 30 percent moisture content before cutting and baling. Another portion of these stalks was dried artificially at 60°C, and allowed to reach equilibrium at about 12 percent moisture in an unheated barn before baling. The bales were then stored under a layer of kenaf bales, a black polyethylene cover or a tarpaulin for about 18 months.

Field dried whole stalk bales stored at 30 percent moisture content, and without any cover except an extra layer of bales, were badly decomposed. This material after storage gave pulps of low yield, high consumption of cooking and bleaching chemicals, and low strength properties. On the other hand, where the moisture in the original bales was only 12 percent and they were stored under cover, the pulp properties and yield of both soda and sulfate pulps were comparable, within the range of experimental error, to those for the materials before storage. There was some indication that the tarpaulin cover was

slightly more favorable for preservation of the kenaf than the black polyethylene.

Again, it has been demonstrated that the outside storage of field dried baled whole stalk kenaf under suitable cover and at 20 percent moisture content or less would be technically successful. It would be reasonable to assume the same case would hold for storage of baled ribbons.

2.6. Review of Studies on Kenaf for Paper Pulp (1950-1975).

2.6.1. Introduction

Apart from the many extensive agronomic and economic studies that have been made on growing kenaf for textile purposes and for paper pulp over recent years, there is a rapidly growing body of technical information covering the pulping of kenaf. As pointed out in Section 1. of this present Chapter I, the major early bibliography (5) on pulping bast fibers did not list a single article on pulping kenaf prior to 1950. In the decade of the 1950's, there were only four significant studies on kenaf pulping and concentrated and worldwide effort on utilizing this raw material for paper pulp did not really get under way until the latter half of the 1960's. Since then, the number of published studies has accelerated and much technical progress in the field has been shown.

The present worldwide interest in kenaf for paper pulp apparently has its roots going as far back as the First World Conference on Kenaf held in Havana, Cuba, in 1958. This meeting was concerned with kenaf for textile fiber. The proceedings (79) of this conference were published by the Agency for International Development of the United States Department of State.

By the time of the Second International Kenaf Conference at Palm Beach, Florida, in December 1964, the results of studies by the USDA on growing kenaf and making paper pulp from it were beginning to materialize and there were three papers on this subject published in the proceedings (80) of the Conference.

By 1967, the interest in pulping kenaf was gaining more momentum and some members of the Technical Association of the Pulp and Paper Industry (TAPPI) in the United States organized the Ad hoc Committee on Kenaf and Related Raw Materials to conduct technical meetings and seminars on all aspects of kenaf for paper pulp. At their sponsored First Conference on Kenaf for Pulp in Gainesville, Florida, in the fall of 1967, there were 34 papers given, along with a demonstration of harvesting and varietal tests and a kenaf pulping run at the University of Florida. The great interest in this subject was evidenced by the fact that there were 96 registrants for the Conference, including a number from foreign countries. The proceedings (81) as well as a number of articles (2,82,83) discussing the meeting and papers were published.

Interest in kenaf for paper pulp continued to grow until, by early 1970, the executives of TAPPI decided to establish the TAPPI Nonwood Plant Fibers Committee for members of TAPPI wanting to contribute to the progress of the industry in this field. The committee decided to attack the entire spectrum of problems of making pulp and paper from nonwood plant fibers in a systematic manner through a series of special functional conferences to be held annually.

The first of these annual conferences was held in the fall of 1970 and the technical papers were published as a TAPPI CA Report (84) in order to place this information in the hands of the participants at the meeting as soon as possible. As a result of the interest shown in the work of this committee and the effort that has been devoted by pulp and paper scientists all over the world to preparing technical papers for these annual meetings, this has become one of the largest and most active committees within TAPPI. Each annual meeting has resulted in the publication of a TAPPI CA Report and of these six CA reports (84,85,86,87,88,89) containing 53 papers, 15 have been on some phase of the subject of kenaf for paper pulp. There has recently been a report on the practical manufacturing aspects of using this fibrous material in full scale experimental mill trials. This continuing interest in kenaf is remarkable when one considers that a pulp mill has never been designed and built specifically for operating on kenaf. This continued encouragement to researchers on kenaf by these programs of the TAPPI Nonwood Plant Fibers Committee can be attributed to the recognition by pulp/paper scientists in all parts of the world that kenaf is a fibrous raw material of major promise for paper pulp.

Another organization that has been active in promoting studies on kenaf is the Intergovernmental Group on Jute, Kenaf and Allied Fibres. This group is under the Food and Agriculture Organization of the United Nations (FAO) and is concerned primarily with textile uses for these fibers. However, over the years the various technical bibliography sections on kenaf prepared by this group for publication by FAO have included many references to the use of kenaf for paper pulp.

In view of these activities by these important organizations, it is anticipated that the efforts that have been and are being exerted on technical studies on kenaf for paper pulp will speed the laboratory findings to full scale commercial application without a long delay similar to that which occurred in the development of bagasse pulp mills. They were not commercially successful until the problem of pith removal was faced and solved after many years and enterprise failures.

Many laboratories and paper companies have obviously been involved in studies on kenaf pulping. Undoubtedly, some very good work has not been published and is not available for this review. However, the Consultants have gathered the publications and documents available from as many sources as possible in order to review the technical data for use in developing the processes and products to be recommended for a Mekong project model paper pulp mill. In addition, it has been judged necessary to discuss briefly what the studies on kenaf for paper pulp have demonstrated so that the collective work and discoveries of the past can be used as the basis for designing the framework for investigations to be done in the future to make kenaf pulping a commercial reality. It is also appropriate that as many of the researchers as possible be recognized for their work and that this Study serve as a comprehensive source of bibliographic information and guide to the literature on the manufacture of pulp and paper from kenaf. If any studies or papers have been overlooked in this survey it is because they were not available to the Consultants or offered nothing new in technical content that was not given elsewhere.

2.6.2. Interpretation of Technical Data Reviewed

In reviewing the great amount of technical data published on kenaf for paper pulp, the Consultants have found most of it derives from studies using conventional pulping laboratory techniques followed in some instances by practical application of the knowledge to actual full scale pulp/paper mill trials.

However, the Consultants find great care must be exercised in interpretation and correlating these data because of a number of confusing factors that will be obvious to anyone who studies the original articles from all these sources. There is the problem that some laboratories have limited resources and facilities and the results in several instances are quite different from those expected to be obtained in commercial practice or with a suitable pilot plant. There are also the variations in results due to the differences in raw material preparation, in testing equipment, and in the technical procedures used by the various investigators.

Such difference in equipment and techniques between laboratories are not unusual but their effects must be kept in mind when data are compared for kenaf pulping studies.

Also, in the case of kenaf, there is another more serious cause of differences and confusion that has not been emphasized or clearly compensated for in their reports by some investigators. This is the history of the physical treatment of the kenaf from the time the green plant reaches maturity in the field to the time the fiber enters the digester. The pulping characteristics, chemical requirements for pulping and bleaching, final pulp yields based on the raw material in its initial form as ripe stalk, and pulp quality will all have been found to vary significantly in these studies, depending upon how the kenaf was treated for each trial. The results depend very definitely upon whether the kenaf was:

- (a) cut green at maturity and pulped immediately, or
- (b) was cut green and dried under roof, or
- (c) was allowed to field dry and leach in the rain for several months before harvesting the stalks, or
- (d) was stored in dense bales under cover or in the open, or
- (e) was stored in bulk using dry or wet storage systems, or
- (f) was cleaned in a wet system for removal of dirt, water solubles, and pith and fibrous fines before being fed to the digester.

There are, in addition to these variables of pretreating the kenaf stalk, the mechanical losses of kenaf fiber for papermaking between the time the stalk is harvested through harvesting, transporting, handling, storage, and cleaning. Therefore, the digester yield data for kenaf given by most investigators cannot be applied, without correction for these losses, back to the green stalk field yield at maturity reported in many agronomic studies. For these reasons, the Consultants emphasize that every one of these historical factors of kenaf stalk or ribbon treatment require serious consideration in comparing the yield data from different laboratories where the detailed history of the treatment of the kenaf is not given.

The weakest link in the whole chain of technical information that has been developed is the fact that there has never been a long term operation of a kenaf paper pulp mill designed in accordance with the modern procedures and continuous processes that have been developed for use on other nonwood plant fibers such as straw and bagasse. In addition, practically all of the documented full scale mill trials or pilot plant runs, where paper has been produced, fail to give the true picture of the properties of paper that could be made from kenaf pulp alone as compared to the standard grades of those products from other raw materials on the world market. It is, unfortunately, the case

that many of the paper machine runs have been made with the substitution of kenaf pulp for a part of the furnish, wood pulp or other nonwood plant fiber pulp such as straw, which only proves that such substitution can be done successfully. However, this does not show the qualities and technical parameters of the major grades of paper and paperboard that could be produced if kenaf pulp were 100 percent of the fiber furnish.

With these limitations and restrictions applying to the interpretation of all these research reports, the Consultants feel the review of the great amount of work that has been done and reported strongly indicates that kenaf for paper pulp could very soon be a successful commercial development from the technical standpoint.

2.6.3. Studies on Kenaf for Paper Pulp by the United States
Department of Agriculture

The USDA formally started a study program on kenaf with the University of Florida at the Everglades Experiment Station in Belle Glade, Florida, in 1943/1944. Its purpose was to assess the feasibility of producing, harvesting, and processing the bast fiber of kenaf for textile purposes. This research in Florida on kenaf for cordage was terminated in 1965 because the prospects did not appear economically promising for commercializing the crop in the United States. However, according to White et.al. (12), this extensive program resulted in the development of: (a) high yielding varieties of kenaf with resistance to anthracnose disease; (b) cultural practices for cordage fiber production; and (c) machinery to top and decorticate the crop and to wash the fiber ribbons.

These studies had a beneficial impact on kenaf production in other countries and resulted in many publications concerning varieties, nematodes, male sterility, insects, weed control, diseases, genetic and cytology and plant improvement through breeding, and related species, which will provide valuable information applicable to kenaf as a pulp crop. A review of these publications is outside the scope of this section of this Study.

Starting in the early 1930's, several branch laboratories of the USDA began the study of the use of nonwood plant fibers, especially crop residues, for pulp and paper. These studies covered not only domestic fibrous raw materials but also various fibers of many species from almost all over the world.

The first experiments on the pulping of kenaf were reported in 1954 by Lathrop and Nelson (7) of the Northern Regional Research Laboratory of the USDA. Separate pulping trials were made on kenaf bast ribbon and the decortivating waste containing the woody stem material of the stalk. The Mechano-Chemical process (44) was used for pulping as it had been developed by that laboratory particularly for use on nonwood plant fibers in small mills for grades of paper where optimum strength and quality would not be required. The very limited tests described in this report indicated that it would be possible to pulp either of these materials by this (M-C) process in which the fibrous raw material is cooked with caustic in a Hydrapulper at boiling temperature at atmospheric pressure rather than cooking under pressure as is done in modern mills to produce higher quality pulp. It should be pointed out that this process would be considered only for use in pulping kenaf in a small mill in a developing country where a low quality of paper would be

acceptable. This process could not be considered for a modern pulp mill in the Mekong Basin.

Beginning in 1956, the Agricultural Research Service of the USDA undertook a program to screen the major species of fibers in the plant kingdom and identify the most suitable plants whose fibers would be most promising for paper pulp. In addition, these would be grown as a crop to compete with other crops in providing a source of income to farmers. Some early notes were published on the program by Wolf and Jones (45,46) in the period 1958 to 1960.

The first technical evaluations were carried out at the USDA, Northern Regional Research Laboratory (NRRL) at Peoria, Illinois, U.S.A. Nieschlag and coworkers (47) published data on their analyses of 58 plant species representing 11 families. From an evaluation of plants for their botanical characteristics, chemical composition, dimensional measurements of fibrous constituents, and yield after sodium chlorite maceration, together with a qualitative physical and visual appraisal, it was found that the two kenaf members of the Malvaceae or mallow family, H. cannabinus and H. sabdariffa, could be given very high ratings for consideration for papermaking fiber. A second part (48) of this study covered an additional 122 species in 22 plant families and, as before, kenaf's excellent rating of potential for paper pulp was not matched by any of the other dicotyledonous plants examined.

Early in 1961, the Forest Products Laboratory of the USDA Forest Service published studies on kenaf pulping, some of which had been carried out in the early part of the 1950's. Chidester and Schafer (8) gave chemical and fiber analyses and pulped H. cannabinus samples from the Philippines of whole stalk, depithed stem, and decorticated fiber tow. It was found that, even with severe cooking conditions of high alkali charge and prolonged cooking time, the pulping action on the woody part of the stem was not satisfactory. However, the kenaf tow cooked much more easily with normal chemical consumption and excellent yield. They demonstrated, at this early date, the outstanding superiority and ease of full chemical pulping of the kenaf bast fiber as compared to whole stalk or decorticating waste. The same analytical data and pulping tests were also reported by Keller and coworkers (49) with more details given for the pulping conditions and pulp strength properties. These authors claimed the strength properties of kenaf pulps were lower than those of hardwood pulps because test sheets of the former were bulky and contained much nonfibrous material. However, the decorticated kenaf pulp was used as 20 percent of the fibrous furnish for a satisfactory experimental run of linerboard with improved tearing and folding endurance tests.

Further studies on kenaf composition and fiber dimensions were published by the USDA in 1961. Nieschlag, Nelson and Wolff (50) gave the chemical and physical analyses for a number of samples of kenaf grown in different locations. Perdue and Nieschlag (51) compared the fiber dimensions of several families of nonwood plant fibers with hardwood and softwood fibers. Among those studied were the Malvaceae, the mallow family which includes kenaf.

In continuation of the search for new fiber crops, Nelson and coworkers (52) at the NRRL used a standard screening pulping test on 61 nonwood plant materials selected from those on which chemical and physical analyses had been made previously. The mallow family plants, kenaf among them, were said to have favorable characteristics for pulp and paper in spite of the fact that the test data show the whole stalk pulps to have been undercooked and not of full chemical cooked bleachable grade.

The year 1962 saw the further technical and economic assessment of kenaf for paper pulp by the USDA. Clark and coworkers (53) gave comparative chemical and fiber analyses for kenaf and its fractions against a softwood and a hardwood. Pulping studies were made on whole stalk kenaf which had stood in the field for 6 weeks after a killing frost before it was harvested. The batch digester pulping studies were made at three levels of chemicals by the sulfate (or kraft), neutral sulfite (semichemical), and soda processes. Following this, a three stage laboratory bleaching of the pulp by CEH sequence was used. The bleached and unbleached pulp samples were used to make 100 percent unbleached and bleached kenaf papers on an experimental paper machine. As expected, regardless of the cooking process, the higher level of cooking chemical enhanced strength development and also resulted in economy of chemicals in bleaching. Strength characteristics of the whole stalk kenaf pulps were superior, at the same freeness levels, to those of commercial hardwood pulp and, except for resistance to tear, were generally comparable with softwood pulp. Differences were not appreciable between soda and sulfate pulps at the same cooking chemical levels. As is the case when pulping wood, the neutral sulfite pulps at high cooking chemical level consumed almost twice the bleaching chemicals as the other two processes and gave somewhat higher bleached yields.

Clark and Wolff (54) continued this work by blending the bleached sulfate and neutral sulfite pulps with various commercial hardwood and softwood pulps processed by kraft, sulfite, and groundwood processes. After a study of the effects of the kenaf pulps on the anticipated

strength properties of the combination of pulps, the authors concluded that papers with a reasonably wide range of physical properties may be made from such blends.

Completing the USDA's publications on kenaf paper pulp in 1962, Trotter (18) made an economic analysis to develop estimates of the field yield of dry matter required for an annual pulp crop, such as kenaf, to be competitive as a raw material for the pulp industry and at the same time provide an equal return to the farmer comparable to returns for established crops. Estimates were developed for: (a) the costs of growing, harvesting, and transporting the annual crop materials, (b) a range in value of the crop materials delivered to the mill, and (c) the per area yields required to equal returns from corn and wheat on lands of different productivity levels. Unfortunately, this economic data is out of date and more recent publications in this area of the subject should be studied for this type of cost information.

By 1965, the scientists of the USDA had further extensive studies prepared on kenaf pulps and paper made therefrom. Clark and Wolff (55) used field dried stalks to prepare bleachable sulfate pulps within a range of active alkali chemical of 15.0 to 19.4 percent for cooking at various levels of cooking liquor sulfidity from 10 to 40 percent.

The bleached pulp yields were in the range of 41.0 to 43.3 percent based on the material fed to the digester and after bleaching to a Hunter brightness of approximately 72.8 to 78.4 percent with 10.2 to 13.0 percent total chlorine in the CEH sequence. These authors reported that the Schopper-Riegler method for pulp freeness determination was used because of erratic results obtained using the Canadian Standard Freeness tester and TAPPI method T227 on nonwood plant fibers. They also pointed out that the average initial freeness value for kenaf whole stalk pulp of 740 ml. S.-R. was about 120 ml. less than for commercial hardwood sulfate and sulfite pulps and 150 ml. less than for commercial softwood sulfate and sulfite pulps studied in parallel tests. Unfortunately, it is not indicated in this paper whether or not the kenaf stalks were precleaned in a Hydrapulper before pulping, as has been done in some other investigations by the USDA laboratories. This step favorably affects yield values and initial freeness and strength characteristics of the resultant pulp.

Data is presented on the products of experimental paper machine runs with the various kenaf bleached pulps. Kenaf whole stalk pulp was found superior to softwood pulp in breaking length and folding endurance and comparable in bursting strength. However, the kenaf

pulps had less resistance to tear. The scientists concluded that kenaf whole stalk bleached sulfate pulps have strength properties which should make them more desirable than hardwood pulps for many purposes, and suitable for many applications where softwoods are now used.

By 1965, Miller (56) reported that the NRRL had received 1,200 samples of about 500 species of plants which had allowed them to evaluate over 850 samples of potential new fiber crops in their new crops screening program. The results of these investigations showed the top rated nonwood plant fibrous raw materials to be kenaf, bamboo, crotalaria, hemp, sesbania, and sorghums. Of these, kenaf received a high rating for pulp manufacture on all counts.

This author (56) reviews the laboratory's earlier papers reporting the fiber ratings, data on the chemical and physical analysis of kenaf, pulping tests, and economic data developed to show the return to the farmer for growing kenaf in comparison with the return from growing other standard crops in the United States.

Miller also points out that the cellulose and lignin in frost killed kenaf were higher and the solubles and ash content lower than in kenaf harvested before frost. This indicates that, where the whole stalk is to be pulped, it could be harvested at a much later date than kenaf grown for twine or textile fiber. Other advantages were also noted for field drying for storage and possible seed production. It was also noted that, because the approximately 20 percent bast fiber fraction in the whole green stalk solids when pulped gives a higher pulp yield than the woody component of the stalk, the final whole stalk pulp should contain 30 to 40 percent bast pulp.

Clark (57) has collected and published data on the dimensional and compositional characteristics of some major pulpwoods and nonwood plant fibers used in papermaking. He reported that, of the more than 1,200 samples furnished by USDA botanists, 750 have been given preliminary ratings and about 100 species have been pulped in laboratory evaluations. Fiber compositional data given for the eight most promising species included those for H. cannabinus and H. sabdariffa.

Analytical evaluations in the USDA's search for new fiber crops were extended, in 1966, by Nelson, Clark, Wolff, and Jones (58). An additional 208 species in 32 plant families were added to the 826 samples representing 387 species in 44 families previously studied and reported for their chemical and physical characteristics. Most of the new fibers evaluated were found to be less suitable for paper pulp than kenaf had been rated in the prior studies.

By 1967, the researchers for the USDA began to realize that the use of only frost killed and field dried stalks of kenaf could present some problems in handling, storage, and pulp production because of bulk, bark discoloration, and possibly bark-core separation. Information was lacking on the utility of pulping green stalks and the influence of maturity on processing and product quality. Clark, Uhr, and Wolff (59) recognized that in harvesting the green plant, the foliage of kenaf might find preferred use as cattle feed because of its protein content and lower pulp qualities. Their investigation consisted of harvesting the kenaf at approximately 30 day intervals, starting 90 days after planting, with the top part of the stem and the leaves kept separately for analysis. A final sample was harvested 87 days after a killing frost so that it had been field dried.

These investigators (59) reported their findings on the chemical compositional characteristics and the fiber dimensional characteristics of the kenaf stalks and tops at the various stages of maturity. Their fiber preparation procedure made no mention of wet cleaning the kenaf in a Hydrapulper before cooking by a standard sulfate pulping procedure in a batch digester using 16.3 percent active alkali at a 10 percent sulfidity level. A standard three-stage bleaching (CEH) evaluation was made to produce pulps of final 75 percent Hunter brightness levels.

This research (59) showed the constancy of cellulose content in kenaf stalks collected at various times, except that the field drying of the frost killed sample while it was being leached by rain provided a material higher in cellulose and lower in solubles than found in the green stalk. It was also found that the bast fiber size was greater at the 90 day harvest than at the later stages of growth.

In the pulping studies (59), it was shown that initial freeness values of the pulps increased with stalk maturity. However, it was discovered that the kenaf pulp was very sensitive to mechanical action so that even pumping it through a centrifugal cleaner resulted in a drop of freeness of up to 105 ml. S.-R. There was also a loss of fines in the screening operation of about 4 to 9 percent of the pulp from the digester which undoubtedly affected the test properties of the pulp. Bleached pulp yields based on screened yield across the digester from green kenaf whole stalks ranged from 44.4 to 48.4 percent for a sample grown in Florida and 39.4 to 40.8 percent (45.0 percent for the field dried sample) for kenaf from Illinois. Bleach requirements ranged from 7.2 to 11.2 percent available chlorine. The pulp strength characteristics were found to improve with the age of the kenaf at harvest time.

One sample of pulp made from the top of the green stalk, from which the foliage had been removed, had a 36 percent yield, higher chemical consumption, lower initial freeness (590 ml. S.-R.), and a very high permanganate number. The pulp also could be bleached to only 56 percent Hunter brightness with a 24 percent bleach consumption. This showed the need for detopping the kenaf, if it is to be harvested green.

It is interesting to note that the data on kenaf pulping in this study (59) was used by Miller (76) for a comparison with hardwood and softwood pulps.

In 1968, the USDA again looked at the economics of kenaf for pulp in the Southern United States. Trotter and Corkern (19) updated the previous study by Trotter (18). Although the price data in their extensive study is now far out of date, they did show the rates of return and costs to the farmer for growing, harvesting, and transporting kenaf under various assumed conditions of area yields as compared to the cost of pulpwood chips and the returns from the growing of timber, and the economic returns from growing cotton, corn or soybeans in various areas. Depending upon the area yields for kenaf, it was possible to calculate the required price, delivered to the mill, of a ton of dry solids equivalent in the form of green, chopped kenaf to equal the return from the other crops. The data given indicated that the cost, based upon equivalent return to the farmer, of kenaf for whole stalk pulp could be in a competitive range with the cost of wood chips delivered to the mill.

In 1969, the USDA continued its series of publications on kenaf for paper pulp with a paper by White (60) on the field yields recently obtained on several varieties of kenaf grown in the Midwest and South of the United States. At the same time, Clark and Wolff (61) published their study showing that population density and plant maturity of kenaf grown in Illinois influence physical and chemical characteristics, not only in whole kenaf but also in its individual components. Their data indicate that, for paper pulp, the kenaf may be grown to maximum productivity and that mature stalks can be field stored for extended harvest without adverse effects on fiber quality. By maceration tests, they showed that the bast fiber content of the samples was about 21 percent of the stalk dry solids and the woody core fibers were about 29 percent of the stalk. This would indicate that, in bleached pulp, the fraction from the bast fiber would be about 40 percent of the total by weight.

Late in 1969, the NRRL made a public demonstration of a semi-commercial run of bond paper containing green kenaf whole stalk bleached pulp as 40 percent of the fibrous furnish, with the rest consisting of wood pulp. Clark (62) has described this research demonstration for scientists attending a TAPPI Nonwood Plant Fibers Committee meeting at Peoria, Illinois. Technical data on this test run were later published by Clark, Cunningham, and Wolff (63). This important study marked the first and only time anything has been published on the pulping of kenaf in a Pandia pilot plant continuous digester similar to those widely used in commercial practice in modern mills pulping nonwood plant fibers for papermaking such as straw, bagasse, and cotton linters.

There were many operational problems reported with the continuous digester located at the Owens-Illinois Technical Center at Toledo, Ohio. Introducing the green stalks of kenaf with about 80 percent moisture content into the screw feeder of the Pandia Chemipulper was no problem other than that only a relatively low rate of feed could be attained due to the slimy, mucilaginous character of the plant juice. This juice was mostly pressed out of the kenaf and separated from it in the screw feeder, but the residual acted as a lubricant so that the plug of kenaf would not feed into the digester faster. It was judged that, on the basis of other experiments, the rate of feed could have been increased if the material had been dejuiced and washed before the pulping operation. Lower chemical requirements and improved pulping would have resulted also from the wet precleaning. The field dried stalks caused difficulties of an opposite nature in that, even with added water to lubricate the plug of kenaf, the screw feeder would not feed uniformly. There were also problems of nonuniformity in cooking shown by variable permanganate numbers and screen rejects as high as 8 percent. These were believed to result from the floating of some of the fibrous mass between the flights of the conveyor in the digester and above the liquor level.

It was also found that, in the chlorination stage of bleaching the pulp at the Forest Products Laboratory at Madison, Wisconsin, there was considerable foaming. The kenaf pulp had a slower drainage rate than wood pulp and formed a thinner sheet on the washers.

Cooking of the stalk chopped in 2.5 cm. lengths was carried out in a Pandia digester with an alkali charge of 16.3 percent active alkali at 10 percent liquor sulfidity. Estimated dwell time in the digester was 7 to 10 minutes at a steam pressure of 8.8 atmospheres gage and a temperature of 180°C.

In order to simulate pulp mill operation, the excessive screen rejects were recooked in a batch digester, rescreened and added to the pulp. This resulted in an unbleached pulp digester yield of about 47 percent for the green kenaf and about 51 percent yield for the field dried stalk. In both cases, the permanganate number was about 20. The pulp from the green kenaf had a lower initial freeness (665 ml. S.-R.) than that (710 ml. S.-R.) of the pulp from field dried stalks. These digester yields in both cases were undoubtedly higher than true overall yields would have been because the green stalks were dejuiced in the screw feeder and the field dried kenaf had already been leached by rain in the field and given a second washing when wet with water and pressed out in the screw feeder.

The bleaching chemical consumption in a CEHD sequence was 10.3 to 11.3 percent available chlorine total to reach Elrepho brightness of 89 and the pulp freeness dropped to 615 ml. S.-R. (320 ml. C.S.F.).

The USDA's marketing economists, in 1970, took a look as far ahead as 1980 to estimate whether or not unused cropland would be available in the Southern United States by that time to be used for growing kenaf for paper pulp. The study by Corkern and Trotter (64) was based on a least cost crop production pattern for seven different possible situations with respect to Federal agricultural policy and the unused cropland that would be available under each situation was calculated. Four of the policy situations resulted in estimates that from 0.94 to 1.07 million hectares of cropland would be unused in 1980 and could serve for growing kenaf for paper pulp. It was also estimated that the capital input for machinery and equipment for growing, harvesting and transporting kenaf would range from US\$2.72 to US\$4.54 per ton.

A review of the work by the USDA on the growing of kenaf and pulping work through 1970 was published by Clark and Bagby (65). Their survey covered the studies up through the successful pilot plant pulping and papermaking runs in which bond paper was produced with kenaf whole stalk bleached sulfate pulp as 40 percent of the fibrous furnish. Another review (12) on the cultural and harvesting methods for kenaf was also published by the USDA in 1970.

The assessment of nonwood plant fibers for paper pulps was continued, in 1970, by Cunningham and coworkers (66) of the USDA. The investigation of 28 new species brought the total studied to 78 evaluated as sulfate pulps using the standard screening procedure for pulping used in the previous studies. They used a so-called Strength Index calculated from bursting, tearing, and folding endurance test results on handsheets made from pulps refined to 600 ml. S.-R. in the

laboratory. A comparative rating of the species judged to be the most suitable for sulfate pulps was established. In this, rating H. sabdariffa was ranked 10th. and H. cannabinus 12th. in the series of pulping potential. A comparison of the Strength Index of kenaf pulp with softwood and hardwood pulp and other nonwood plant fiber pulps was also shown for various freeness levels during refining trials in the laboratory beater. It was concluded that, although H. cannabinus was ranked 12th. in order of Strength Index, it would continue to be the prime potential nonwood plant fiber for pulp because of its high productivity and other agronomic characteristics.

As an indication of awareness that storage of whole stalk kenaf for paper pulp would be a major operational problem where mechanized harvesting of the green stalk would be employed, Clark and coworkers (40) of the USDA, in 1970, reported on storage tests of green kenaf ensilage and the quality of the pulps that could be made after periods of prolonged wet storage in comparison to field dried stalks stored in bales, either with or without cover protection. The results of these studies have already been discussed in detail in Sections 2.5.2. and 2.5.3. of this Chapter I reviewing the studies on kenaf storage. They recognized that the deterioration of vegetative tissue, which begins due to enzymic and microbial action as soon as a green plant is separated from its stem, has to be controlled if green kenaf is to be used for paper pulp manufacture on a year around basis and stored for any period of time. Because the tops of kenaf contain up to 9 percent glucose and the stem 6 percent at maturity, it was logical that ensilage under anaerobic conditions to produce lactic acid in the stored kenaf should be investigated to determine if preservation of the cellulose content of the green kenaf by this method of storage could be achieved equal to that resulting from covered bale storage of field dried stalks.

In their pulping investigation (40) of the samples stored under different conditions, the kenaf was cooked in a batch digester for 2 hours at 170°C. For baled kenaf, the cooking liquor charge was 16.4 percent active alkali at 33 percent sulfidity, and for ensilaged green kenaf stalk they used 16.3 percent active alkali at 10 percent sulfidity. Consideration of and calculations from the data given for the unbleached pulps show that the actual overall pulp yields, based on the oven dry equivalent weight of the solids in the green kenaf when it was placed in storage, were in the case of green kenaf usually much lower than reported for yield of screened pulp based on the kenaf dry solids equivalent to the digester, as shown by the following accompanying figures in parentheses. Baled field dried stalks, digester yield 48.2 to 50 percent originally, after stored for

18 months in a covered rick showed unbleached pulp yields based on original material of 42.9 percent (43.6 percent) in the interior bales, 41.3 percent (41.3 percent) in the exterior side bales, and 44.6 percent (44.6 percent) in the top bales under cover. In an uncovered rick, the corresponding yield values were 33.11 (47.5), 37.1 (46.1), and 21.2 percent (42.8 percent), the latter showing a badly deteriorated layer of bales on top. These were compared to a sample stored in the barn which gave a yield of 46 percent (46.2 percent) pulp.

For the green kenaf stalk samples that were not wet cleaned before pulping, the original stalks gave a 36.4 percent (34.7 percent) yield of unbleached pulp if the tops were left on and 38.2 percent (38.2 percent) yield if the tops were removed. For the samples which had been ensilaged for 500 days and which were wet cleaned before pulping, the yield from the acid treated kenaf with tops was 23.6 percent (45.0 percent), that for kenaf without tops without treatment was 27.1 percent (49.2 percent), with acid treatment 29.4 percent (49.5 percent), and with molasses 25.3 percent (49.9 percent). The sample of green kenaf submerged in water under anaerobic conditions for 100 days gave a yield of 38.3 percent (46.3 percent), whereas the sample treated by daily immersion in water and draining for 100 days resulting in aerobic conditions gave a yield of only 20.0 percent (40.6 percent) pulp. There is a most significant aspect of these low overall pulp yield figures, as compared to the digester yield figures generally published by most investigators. It is that they bear out the long-time estimates by the Consultants that the yield of bleached kenaf whole stalk pulp, based on the solids originally in the green stalk, will not exceed an average of about 30 percent. For field dried stalks that are partially rain leached and, based on the solids remaining, the overall pulp yield will not appreciably exceed 35 percent, when all the losses in handling, transporting, storing, and wet cleaning are taken into consideration.

It was reported (40) that the Strength Indices for the pulps from the field dried stalks stored in the covered rick were equal to or better than the original material or that stored in the barn. Pulp from the top bales of the uncovered rick had very poor pulping characteristics, a low initial freeness value, and a low Strength Index value. However, the pulp from the interior and exterior side bales of the uncovered rick did not show a very significant drop in pulp strength properties.

In the case of the pulps from the samples of green kenaf stored by the different procedures, the Strength Indices improved for the wet cleaned samples, with or without storage, as compared to the

original green stalk not wet cleaned. The detrimental effect of the green plant tops on pulp quality was definitely shown. Adequate preservation of pulp strength properties was given by the various ensilage treatments and continuous immersion resulted in a pulp with the highest Strength Index. On the other hand, the kenaf stalks subjected to aerobic decomposition by daily immersion and draining had a very low Strength Index.

In considering these data for yields, the Consultants again want to emphasize and caution that they cannot be compared for the field dried kenaf samples with the sample of green kenaf, because the field dried kenaf had lost some of its solids due to rain leaching while standing in the field, whereas the green kenaf that had been stored had undergone microbial and enzymic action and was also wet cleaned, with attendant further losses of solubles and fine fibers, before pulping. However, the data significantly show that pulping characteristics and pulp strength quality can be maintained by both bale storage of field dried stalks in covered ricks and in anaerobic bulk storage of chopped green stalks using normal or special (with additives) ensilage systems as well as submergence in water. The storage of green kenaf under aerobic conditions was shown definitely to be highly detrimental to preservation of cellulose from the green kenaf and the strength of the pulp which resulted.

The separate pulping of the kenaf bark and woody fractions was beginning to be presented for public attention by the USDA by 1971. Clark and coworkers (67) discuss previously unpublished work done by the NRRL about 1957 in which the refuse from the decorticating waste from kenaf textile fiber production was made into a pulp for corrugating medium. In addition and somewhat later, this laboratory made pulps from two samples of bast fiber from field dried stalks. For one sample, the brittle dry stalks which had been stored for several years were passed through crimping rolls. The core was brittle, broke into small pieces, and with moderate shaking the core separated from the bark. For another sample for pulping, the ribbon from dry stalks was combed to remove the nonfibrous portion of the bark. The results of this investigation were very impressive and show that the separate pulping of the components of kenaf, based upon the possibility for developing an inexpensive and practical way to separate them, should have been the subject of intensive investigation before that time. Kenaf bast ribbon pulped with an active alkali charge of 16.4 percent at a liquor sulfidity of 34 percent gave an unbleached pulp yield across the digester of 52 percent and a final bleached pulp yield of 45 percent following consumption of 8.3 percent available chlorine in a CEH laboratory bleaching sequence to 80 brightness. The initial

freeness was 860 ml. S.-R. and the Strength Index of the pulp was 3500, much higher than the 2200 to 2500 value which USDA studies have found for the best whole stalk pulps.

In the case of the combed ribbon with approximately the same active alkali charge and 10 percent liquor sulfidity, the unbleached pulp yield across the digester was 59 percent and the bleached yield was 57 percent under the same bleaching conditions with a consumption of only 3.1 percent available chlorine. The initial freeness and Strength Index of this pulp were practically identical to that of the pulp prepared from the ribbon that had not been combed.

Because of the results obtained on pulping the bast fibers, green kenaf was cut and artificially dried to retain the solids in the fresh stalk. It was later found that the bast did not separate from the core as easily as it did in the case of the field dried, weathered stalks. Chemical analyses were reported for the fresh and dried original unfractionated stalks and for the dried bast and core materials. As compared to the core material, the bast had somewhat higher crude cellulose content (57.4 percent vs. 51.2 percent), twice the hot water solubility (14.0 percent vs. 7.8 percent), almost three times the wax content (1.4 percent vs. 0.5 percent), lower pentosans (16.1 percent vs. 19.3 percent), less than half the lignin (7.7 percent vs. 17.4 percent), and almost twice the ash content (5.5 percent vs. 2.9 percent). The bark-core ratio with all solubles included was found to be 42:58 for this situation, where the kenaf was cut green and artificially dried.

The standard pulping procedure of a two hour cook at 170°C with a 16.3 percent active alkali charge of liquor at 10 percent sulfidity was used for the two separate components for kraft pulps. Soda pulps were also made under comparable conditions as well as at lower active alkali charge (8.15 percent) and one hour cooking time for the bark.

The bleached grade sulfate or soda pulps from the bark had digester yields in the range of 51 to 55 percent with initial freeness values of 740 to 785 ml. S.-R. and normal Strength Indices of 3400 to 3500 for this fiber. In comparison, the unbleached core pulps were at about 45 percent yield with initial freeness values in the range of 565 to 580 ml. S.-R. The bleach requirements of these soda and sulfate pulps from core material at this yield would be quite high. In addition, the Strength Indices ranged between 1700 and 2000. The authors published a very interesting chart showing the Strength Indices for various kenaf pulp samples at various degrees of refining in the laboratory beater. The whole stalk kenaf pulp, as would be expected,

had Strength Indices about halfway between those of the bark pulp and the core pulp.

By 1972, the researchers at the NRRL were beginning to make information available on the treatment of kenaf by some of the processes already used in the sugar industry for bagasse preparation for pulping. Bagby et.al. (68) pointed out the necessity for maintaining a year around raw fiber source, based on a seasonal agricultural crop such as kenaf, from which pulp of constant, uniform quality might be produced. Prior analytical evaluations by Bagby, Wolff, and Cadmus (69) had been made on the juice removed by pressing green kenaf before storing it for paper pulp production.

In the paper pulp study (68), two basic designs of dejuicing equipment, the screw press and sugar mill crushing rolls, were evaluated for their suitability for processing green kenaf. When the green kenaf stalk was processed at the sugar mill, the slitting knives reduced the bark to ribbons and long strands of bast fiber fouled both doctor blades and rolls. Precutting the stalks to 30 to 40 cm. length solved much of the problem.

Another sample of green kenaf was prepared by mechanically harvesting the stalk with foliage with a forage chopper, shredding it, and pressing it one (to 35 to 40 percent solids) or two passes (45 percent solids) through a commercial screw press. A further step was taken on part of the sample with foliage to remove additional solubles and fines, such as epidermis and parenchyma cells. In order to do this, single-pass screw-pressed green kenaf was water scoured in a Hydrapulper and the water was discharged through a fine screen. Fibers retained by the screen were returned to the Hydrapulper and the scouring treatment was repeated two more times. In this step, the water with fine particles of fiber debris was filtered in a heavy duck bag and 7.5 percent of the original solids in the dejuiced kenaf were collected. The fiber from the Hydrapulper was then screened over a Jonsson screen with 0.10 cm. diameter perforations and it was found that another 2.5 percent of the original solids passed through the screen. When the cleaned fiber yield was determined, it was found that 17 percent of the original dry kenaf solids left after dejuicing the green kenaf had been removed by this drastic wet cleaning procedure.

Field dried kenaf stalks harvested several months after being killed by frost were also wet scoured in the Hydrapulper, followed by the Jonsson screening process. In this case, the major solids were determined in a centrifuge rather than by filtering. The solids collected in the centrifuge amounted to 7.0 percent of the solids in

the original field dried stalks and the solubles and fines not removed by the centrifuge were an additional 21.0 percent of the original material, making a total of 28 percent of the original solids in the field dried stalks that had been removed in the wet cleaning.

In this study (68), the effects of dejuicing and wet cleaning the kenaf on the chemical analysis of the samples are shown. Contrasted with untreated kenaf, the advantages realized by dejuicing and wet cleaning were lower chemical requirements for pulping and bleaching and faster draining pulp. The authors concluded that the treated green and field dried kenaf samples have similar properties and this similarity also extends to the pulps produced from them.

There is much data given in this extensive study that will be useful in the design of the Mekong project mill. However, the Consultants feel the detailed data in this article should not be incorporated in this review at this time. The yield data are based on digester yields after probably as high as 30 percent of the original solids have been removed in the more drastic combined dejuicing and wet cleaning procedures and are therefore somewhat misleading as stated. Also, in two cases as much as 22 percent and 37 percent of the pulp had been rejected in screening and the yield data for bleached pulp are obviously based on bleaching of only the unbleached pulp accepted by the screen. Interpretation of the Strength Index data is also difficult because the actual changes in the burst factor, tear factor and folding endurance relationships cannot be determined. At any rate, the study makes it quite clear that wet cleaning the kenaf before pulping will improve its condition for pulping, just as it does in the case of other nonwood plant fibers, such as bagasse, in commercial practice.

Another very significant study was published in 1972 on the pulping of kenaf bark and core separately. Touzinsky, Clark, and Tallent (70) had undertaken this program to identify and assess the factors affecting hydration and drainage of the two types of kenaf pulps in comparison with the whole stalk pulp and softwood pulp. The kenaf stalks were harvested green near maturity and the stalks were partially dried to about 30 percent moisture and stored in a barn until processed. Thus, the original solids in the green stalk were preserved in the kenaf. The bark and core sample components were separated manually and samples were chopped into 2.5 cm. pieces. The authors made no statement as to whether or not the kenaf samples were wet cleaned before pulping but, from the digester yields obtained, it appears this important step had been taken in preparation of the kenaf. Pulping followed the standard batch procedure using 16.3 percent active alkali charge for liquor at 10 percent sulfidity and at a liquor ratio of 7:1. The cooking cycle

was 0.5 hours to temperature and two hours at 170°C. Pulp samples were refined in both a PFI mill and a TAPPI Standard Laboratory Beater. For the mixed furnishes, where the two component pulps were to be mixed before or after refining, the ratio used was 43 parts of bast pulp to 57 parts of core pulp in order to match the ratio of bast to core fiber in the whole stalk and, at the same time, to compensate for differences in yields.

For comparative purposes, chemical analyses were given of the whole stalks, bast, and core samples and their resultant pulps. The pulping data given were for a standard cook that was used for all three samples, rather than cooking each component of kenaf under conditions that result in optimum pulp properties for that particular fiber as would be done in commercial practice. The bast fraction gave higher yields of both bleached and unbleached pulp, a much lower Kappa number, a higher initial freeness, and had a third the consumption of bleaching chemicals as compared to the core pulp. Their comparative laboratory beater strength data for these two pulp samples have recently been released by the NRRL (71) and are shown in Section 2.3. of this Chapter I. The evaluation of the pulps in the Valley beater and the PFI refiner revealed that the woody core pulp beat more rapidly than the bast pulp and was the cause of the rapid reduction in freeness of kenaf whole stalk pulp. Physical properties of blends of bast and core pulps correlated well with pulp from kenaf whole stalk and those estimated for mixtures based on the data for the separate pulps.

The analyses of the separated bast and woody core show that the high lignin content of the core requires a stronger pulping and bleaching procedure at higher chemical consumption to reach a brightness level corresponding to that for pulp made from the bast. The differences in the two components were said to warrant their separate pulping if optimum pulping conditions are to be used. Otherwise, if the whole stalk is pulped, the cooking conditions are at best a compromise, resulting in overcooking and overbleaching the bast fiber and undercooking and underbleaching the core material to reach the optimum quality for the combination of the two fractions cooked together. This could easily have been demonstrated for the pulping step by cooking the separated components in baskets in the same digester charge.

The authors (70) also published their findings that, with the woody core pulp, the Canadian Standard Freeness value decreased with refining to a minimum and then increased with refining beyond that point due to the core fiber passing through the large perforations of the CSF tester. The effect is not noticeable with the Schopper-Riegler Freeness Tester. This indicates the validity of what others had pointed

out previously at the USDA laboratories to the effect that the CSF instrument is not as suitable for this test on nonwood plant fibers as is the S.-R. device.

Microscopic examination of the two component pulps showed the bast pulp fibers to resemble those of northern softwoods in shape and structure. The core pulp contained a number of different kinds of cells with the true fibers being shorter, wider, and having thicker walls than bast fibers. Other types of cells studied with microscopical and scanning electron microscopical techniques by the authors were discussed.

In 1973, Touzinsky and coworkers (72) extended the preceding study by Touzinsky et.al. (70) to determine the optimum pulping conditions for producing bleachable grades of kenaf bark and core soda pulps. It was clearly stated that the air dried green kenaf bast and core samples after long term storage had been wet cleaned before pulping and that this removed 29.5 percent of the extraneous materials and water solubles from the bast and 18.5 percent from the core.

In the pulping studies, a series of cooks were made in which the time at temperature and the active alkali charge were varied. Using the significant statistical correlations developed from the pulping data, a quadratic equation was used to calculate a series of contours of the specific property, yield of crude bark pulp, with respect to cooking time and active alkali charge used. The validity of the predictions from these diagrams was tested by preparation and the close characterization of three pulps (two bast, one core) not used in developing the correlations.

In the series of pulping trials, the cooking temperature was 170°C and a 7:1 liquor-to-solids ratio was used. The active alkali charge and the time at temperature were varied. It was found that bast material readily cooked to produce bleachable grade pulps with 1 percent or less rejects and Kappa numbers below 22 at 15 percent or greater active alkali and 1.5 hours or longer cooking time. To achieve a similar degree of cooking, core material required either 18 percent active alkali and 2 hours or 21 percent active alkali and 1 hour time. The bast unbleached pulp crude yield from the digester was given as 64.7 percent with a Kappa number of 21.2 and initial freeness of 835 ml. S.-R. The core pulp at 18 percent active alkali gave a digester crude yield of 48.5 percent with a Kappa number of 21.8 and initial freeness of 490 ml. When the yield values are corrected back to the original dry solids in the air dried kenaf before the wet cleaning step, the yield of unbleached bast pulp becomes 45.6 percent and the yield of core pulp is 39.5 percent.

In general, the study showed that the burst factor of the bast pulps decreased with increasing active alkali and cooking time, whereas the reverse occurred for the core pulps. In general, tensile or breaking length of both the pulps followed the same trends as the burst factor. Tear factor was reported to have no clear cut trend for bast pulps, but it tended to increase for core pulp at increasing active alkali and cooking time. It was also found that, as with wood pulps, the initial freeness of core pulps decreased with increased degree of cooking whereas the initial freeness of screened bast pulp tended to be lower for the less cooked pulp. Microscopic examination of these bast pulps showed a larger proportion of fines in the less strongly cooked pulp. It was concluded that this phenomenon resulted from fine parenchyma cells becoming free in the pulp before the bast fibers were fully dispersed and thereby lowered the freeness.

Another investigation published in 1973 by Bagby, Clark, and Cunningham (41) covered the pulping of wet processed stored green kenaf. This was a continuation of investigations, in 1970, by Clark and coworkers (40). The scheme and conditions for anaerobic preservation of both dejuiced foliated and defoliated green kenaf whole stalks and separated bast ribbon and woody core material for 9 months have been discussed in Section 2.5.2. of this Chapter I. After storage, the various samples were wet cleaned and then subjected to chemical analysis and pulping and bleaching trials for comparison with the original samples before any treatment or storage. It was found that recovery of cleaned residues of the various samples ranged from 52 to 73 percent of the original equivalent oven dry solids in the kenaf samples before treatment.

Soda pulps were prepared by the standard procedure used by the NRRL in previous studies. The cooks were made using 16.3 percent active alkali for 2 hours at 170°C. The bleaching sequence used was CEH and it appears an attempt, not successful in some cases, to reach 80 percent brightness was made.

The chemical analysis showed that, compared with the original materials, cleaned residues recovered from storage contained a total of 20 to 40 percent more cellulose, pentosan, and lignin combined and correspondingly less extractives, nitrogenous protein, and ash. Less caustic was consumed in pulping the cleaned storage residues than by unstored materials. Pulps from cleaned residues had very much lower Kappa numbers which were verified by their reduced demand for bleaching chemicals to reach a high level of brightness. In general, this research shows the advantages resulting from wet cleaning pretreatment before pulping the kenaf extend to green plants with and without foliage

and the bast and woody core fractions. These advantages are enhanced when the kenaf has also been stored under anaerobic conditions, with and without preservatives.

The data show in a very dramatic manner, by using a standard pulping procedure with fixed active alkali charge, the improvements in pulping and bleaching resulting from wet cleaning before and after storage of all forms of kenaf fiber. However, the final overall bleached yields and bleaching chemical consumptions can not rigorously be compared for any type of kenaf pulp except to some extent for the various samples in each case which have been stored before wet cleaning. Actually, the investigation program resulted in the cooking of as many as two very different raw materials in three of the cases and three in another. These would be the original kenaf samples in all cases, the wet cleaned sample in addition in the case of the foliated dejuiced sample only, and the stored and wet cleaned samples in all cases. Comparison of the various preservatives used in storage based on the data for bleaching chemical consumption and overall bleached pulp yield would not be greatly subject to question for the stored and wet cleaned samples, if they had all been bleached to approximately the same brightness level for samples which had two or less percentage points difference between the crude and the minus 8-cut screen unbleached pulp yields. This would be made possible by the fact that, in each case, the preservative system used for storage and the wet cleaning before pulping tends to insure that the samples of fibrous raw material will all pulp about the same under equivalent conditions. For the original kenaf samples except the bast ribbons, for practically all of the stored and wet cleaned samples of woody core material, and a few others of the stored and wet cleaned whole stalk kenaf, the difference between the crude unbleached pulp yield and the yield of screened pulp taken for bleaching trials can not be ignored. The screenings would have had a significant effect on the bleached pulp yield and the bleaching chemical consumption, if they had been incorporated in the pulp to be bleached, either as refined or recooked rejects accepted by the screening system.

In view of these factors it can be said that the standard screening procedure followed in this study shows that wet cleaning and the various storage treatments followed by wet cleaning are very effective and allow comparisons between the samples of unbleached pulps in any one case. However, valid comparisons of the bleaching data, even within any one case, are complicated by the problem of the screen rejects not being recirculated in the pulping system and the fact that the unbleached pulps in some cases are not cooked, as would be done in commercial practice, to the optimum Kappa number level for economical bleaching and highest bleached pulp strength properties.

From the data in this study (41), it appears that overall bleached soda pulp yields from raw material which had been stored and wet cleaned can be considered to have been as follows:

Dejuiced Foliated Green Whole Stalk Kenaf	26 to 30 percent
Defoliated Green Whole Stalk Kenaf	30 to 35 percent
Green Kenaf Bast Ribbon	40 percent
Green Kenaf Woody Core Material	23 to 27 percent

Further cooking and bleaching studies have been made on the whole stalk, bast, and core of kenaf by Niyomwan, Clark, and Cunningham (73). Green kenaf stalks harvested at maturity were air dried at less than 52°C to about 30 percent moisture content and stored in a barn and this retained the dry solids originally in the green stalks. Before pulping, the samples were wet cleaned by the standard procedure used at the NRRL.

Using standard cooking procedures, except for variation in the percentage of active alkali digester charge, for the three different forms of the kenaf, bleachable grade pulps with Kappa numbers very close to the target of 20 were produced. On the unfractionated stalk with an active alkali charge of 17.5 percent, the crude yield of unbleached pulp was 54.0 percent, calculated by the Consultants to be a 41.6 percent overall yield based on the original weight of oven dry solids in the original green kenaf. To attain the same pulp Kappa number on the bast and the core material, the active alkali charges were 13.3 percent and 18.5 percent respectively, the crude yields 61.9 percent and 46.0 percent, and the calculated overall yields of unbleached pulps were 43.64 percent and 37.5 percent.

In this study, the experimental bleaching was divided into two phases: (a) an exploratory phase of chlorination and extraction; and (b) a four stage bleaching with chlorination including chlorine dioxide, caustic extraction, treatment with sodium hypochlorite, and a final chlorine dioxide stage, making the bleaching sequence CdEHD. Partially bleached samples of all three types with the most favorable characteristics resulting from the CdE treatment were then fully bleached, using following hypochlorite and chlorine dioxide stages, to the brightness range 76 to 84 percent GE with a bleach chemical consumption range of 4.9 to 5.8 percent available chlorine. Applying the full four stage bleaching sequence to the pulps caused drastic decreases in disperse viscosity and significant increases in hot alkali solubility for all pulps. It was indicated that the hypochlorite stage of bleaching may have been responsible for the pulp deterioration observed on the basis of chemical analysis and reduced Strength Indices.

A number of additional studies by the USDA have been published in 1975. Bagby, Cunningham, and Clark (43) compared the physical and chemical characteristics of soda pulps for (a) green, (b) field dried, and (c) stored whole stalk kenaf and (d) bark and (e) woody core to sulfate pulps from the same raw materials. It was found that the strength characteristics of the kenaf soda pulps, except in the case of the core pulp, were equivalent to those of their respective sulfate pulps, and yields were equal. The drainage rate was improved in the soda pulps over the sulfate pulps. This factor, together with the favorable environmental aspects of the sulfur-free soda technique, enhance the value of pulping kenaf by the soda process. This is the same situation as has been recognized in the pulping of other nonwood plant fibers, such as bagasse.

In this investigation (43), the wet cleaning procedure that has been used for other studies was not used (74) by the NRRL scientists and the only samples which had soluble substances removed from the kenaf before the digester were the partially dejuiced foliated green kenaf and the field dried stalks, particularly from those baled and on top of the pile stored outside without cover.

The yield and pulping data in this report are comparable to those found in other recent USDA reports on pulping kenaf. The appreciable loss in yield and Strength Index for the top bale in a rick stored outdoors without cover was clearly shown.

The most recent study published by the USDA is that on the pulping of kenaf roots by Bagby, Cunningham, and Adamson (75). This is very interesting because it has been estimated that collecting the root could increase the fiber yield by a minimum of 10 percent. Materials processed and cooked on a comparative basis included separated stems and roots from mature kenaf plants harvested green, and seven weeks and also three months after frost. Also included were roots left standing in the field from 4 to 19 weeks after the stem portion of the plant had been removed.

The chemical compositions of the various samples were determined after they had been wet cleaned by the NRRL's standard procedure. The standard pulping screening procedure was used on the various samples. The pulps prepared from the root segments were similar and those from the stems were also. Bleached and unbleached pulp yields were normal for kenaf and the bleaching chemical consumption was more than twice as high for the roots as for the stems. Roots and their resultant pulps were found to have chemical and physical properties suggesting a greater concentration of core components than those of the stem. Although bast

like fibers extended on the roots below ground, they decreased at the root's extremity and deteriorated with weathering in the ground so that the roots began to become more corelike in composition. With weathering of roots in the ground for about 3 months after frost, the bleached pulp yield decreased by about 10 percent. At the same time, the Strength Index and the initial freeness of the pulp from roots also gradually decreased.

Based on the data given in this and previous studies by the NRRL, it appears that satisfactory pulps for some paper grades can be made from kenaf, including the roots and foliage, along with the whole stems. This is particularly the case if proper bulk storage systems and wet cleaning processes are used to prepare the fiber for the digester.

2.6.4. Other Investigations and Reports on Kenaf for Paper Pulp in the United States

2.6.4.1. Work at A.B. Dick Company on Stencil-Base Tissue Pulp

The kenaf pulp of first known record (6) was made in a laboratory of the A.B. Dick Company in the United States in 1949 and is listed as Sample No. 1 in the TAPPI Library. Glading (198) has reported this was actually bast fiber pulped by a mild sulfate cook in an investigation to find a replacement fiber for abaca for use in stencil-base tissue. Although a pulp of good papermaking quality was achieved, it did not have the extremely high strength characteristics required to allow substituting it for abaca fiber.

2.6.4.2. Trials to Produce Mechanical Pulp at Bauer Bros. Co.

During 1967/1968, a number of basic studies on kenaf mechanical pulping were carried out for clients at the Bauer Bros. Co. laboratory by Ginaven, Charters and Miller (199) using commercial equipment. A paper mill trial was also made elsewhere with the pulp produced. The purpose of the investigation was to produce refiner mechanical pulp with little or no added chemicals. The pulping system consisted of a continuous screw press followed by one or two stages of disc refiners. It was found that the screw press (Pressafiner) readily

accepted chopped kenaf in random lengths of 1 to 15 cm. at a moisture level of about 80 percent to yield a press cake at about 30 to 40 percent oven dry solids at a power input of 45 to 80 kwh./ODMT. In addition to removing some dissolved solids of possible value, the screw press was an excellent means for pre-fiberizing the kenaf whole stalk for the refining step. With a double revolving disc refiner, a fiber useful in board products was prepared in a single pass. It was found that mechanical pulp for paper grades required two stages of refining and an improvement resulted if the first stage refining was done in a steam-pressurized (Thermal-mechanical) refiner. It was found that 500 ml. C.F.S. pulp required about 750 kwh./ADMT and 200 ml. C.S.F. pulp 1,200 kwh./ADMT. Also, the age and treatment of the kenaf as well as variables in the processing equipment were said to produce wide variations in test data.

2.6.4.3. First Conference on Kenaf for Pulp

As mentioned earlier in Section 2.6.1. of this Chapter I, by 1967 the interest of the United States paper industry in kenaf resulted in the formation of the TAPPI ad hoc Committee on Kenaf and Related Raw Materials. This committee sponsored the First Conference on Kenaf for Pulp which resulted in publication of the Conference Proceedings (81) as well as several papers (2,82,83,90) discussing the meeting. Of the conference papers there were a number, besides those already reviewed that were given by the USDA, which indicated consideration was being given to kenaf pulping by a number of individual companies.

2.6.4.4. Plan of J.E. Atchison to Use Kenaf Bast Fiber for Mill in Argentina

Atchison (9) spoke of consideration being given to the pulping of retted kenaf bast fiber costing US\$88.00/MT in about 1959. for a mill in Argentina to produce the required long fibered chemical pulp to use with bagasse pulp in printing and writing papers. Various suggestions, which are still valid today, were made for separating and separately pulping the two components of the kenaf stem. The problems of slow drainage and foaming of the kenaf pulps were recognized and the necessity for proper storage and wet cleaning procedures to reduce the problems was emphasized.

2.6.4.5. Systems for Preparing and Pulping Kenaf
Proposed by the Black Clawson Co.

The problems of processing kenaf into paper pulp were discussed by Herbert (91) at the Conference. It was stated that proper storage conditions and wet cleaning of the kenaf, if it acts similarly to bagasse, would minimize most of the problems. System outlines for reclaiming forage harvested kenaf from bulk storage by wet handling methods as well as the direct processing of field dried baled material to the digester were described.

A recent publication by Felton (97) of the Black Clawson Co. outlines system concepts for fibrous raw material preparation and continuous pulping of nonwood plant fibers including kenaf. The baled kenaf bast ribbons are cut in a rag cutter and wet processed in a Hydrapulper to remove dirt, solubles and non-fibrous fine cells before feeding the fibrous raw material to the horizontal tube-type continuous digester.

2.6.4.6. Work on Kenaf Pulping at Eastex, Inc.

A report on the laboratory studies on pulping whole stalk kenaf at Eastex, Inc. was made at the Conference by Robinson (92). Field dried stalks after frost killing were chopped in a silage cutter and were pulped at the same conditions used for pulping hardwoods. The unbleached pulp yield after screening was 42 percent with 2.7 percent rejects. The laboratory beater test showed the kenaf whole stalk pulp took a quarter the beating time for hardwood pulp and one-eighth that for pine pulp to reach a 400 ml. C.S.F. value. The kenaf pulp was reported to have lower bursting strength than hardwood pulp and was significantly lower in tearing strength. Laboratory bleaching trials to as high as 87 percent brightness were made with the CEHD bleaching sequence.

2.6.4.7. Kenaf Storage and Pulping Tests by Kimberly Clark Corp.

Another speaker at the Conference, Rowlandson (93), mentioned work done on kenaf storage and pulping by Kimberly Clark Corp. at Coosa Pines, Alabama, but no technical data were given.

2.6.4.8. Pulping Studies at the University of Florida on Kenaf

Actual pulping trials on kenaf whole stalk during the Conference were carried out by Nolan (94,95) at the University of Florida Pulp and Paper Laboratory. In order to check the kenaf stem for pith in the woody portion, some chlorine dioxide purifications were undertaken. The air dried stalk sections were hand stripped and found to be 32 percent bast ribbon and 68 percent core containing the central pith. When the central pith was removed and the rest of the core material macerated, it was found to contain additional fine, non-fibrous material. It was suggested that much of the pith could possibly be removed by passing the green stalk through an attrition mill with spiked toothed plates to fiberize it. Dry stalks would be first heated and soaked in a boiling dilute sodium carbonate solution to soften them before the fiberizing. It was suggested that the pith could be washed out of the fiberized kenaf by running the material over an inclined screen with sprays. Following this, a suitable wet storage system of the Ritter Process would be used to make easier further separation of pith from fiber.

In the pulping demonstrations by Nolan (95), green kenaf stalks were shredded in a Vertiflex attrition mill for pulping comparison with cut pieces of kenaf stalk. It was found the shredding of the kenaf before pulping under optimum conditions was advantageous in reducing screenings that resulted when cooking the cut pieces of stalk at the same conditions.

2.6.4.9. Laboratory and Mill Scale Pulping and Papermaking Trials at Hudson Pulp and Paper Corp.

Semi-commercial farm scale investigations of the growing, harvesting, handling, and storage of whole stalk kenaf for the Hudson Pulp and Paper Corp. pulping tests in Florida have been described by Uhr (20,30,83) and Guttry (21) in Sections 2.3., 2.4., 2.5.1., and 2.5.2. of this Chapter I. The actual mill full scale pulping trials which finally resulted were described in detail by Guttry (21,83) and Uhr (29,30) at the 1967 Gainesville Conference.

The first investigations in pilot plant laboratory pulping equipment as described by Guttry (21,83) indicated screened pulp yields equivalent to those from hardwoods and softwoods. Data from these tests led to the conclusion that kenaf whole stalk pulp would be inferior to pine pulp in tearing and bursting strength values and inferior in bursting strength but superior in tearing strength to hardwood pulp. The drainage problem of the pulp in comparison to wood pulps was immediately recognized.

For the mill trial, six acres of mature stalk and four acres of immature kenaf were defoliated by spraying defoliant from a plane and harvesting was done with two forage harvesters to cut about 2 cm. length pieces. Transportation of the kenaf was by field wagons and dump trucks. Difficulties were encountered with the harvesting and transporting equipment actually used for this trial as an expedient. However, such is not expected to be the case when proper equipment, such as used for harvesting sugar cane in large mechanized operations, is adapted to kenaf farming.

Loading the two large batch digesters with the green kenaf proceeded satisfactorily and the digester loading of kenaf, on a green basis at 70 to 75 percent moisture, was not very far below the normal load of green wood chips. The cooking liquor added contained 21 percent active alkali on the basis of the oven dry content of kenaf in the digesters and without adding any black liquor to the cook the liquor to solids ratio was 5:1 due to the high moisture content of the kenaf. Although the first directly steamed digester of kenaf gave some difficulties in cooking, the second unit came onto full cooking pressure at 6.8 atmospheres gage after 85 minutes and was blown 10 minutes later satisfactorily. Difficulties were experienced in the hot stock screening system ahead of the unbleached pulp washers. The 2.3 mm. diameter plates scaled over with mostly long bast fiber so the 3.0 mm. diameter plates with increased dilution were used and the rejects were recycled, refined, and returned to the screens. The pulp drained very slowly on the first stage washer drum and seal-over was a problem but improvement resulted on the second and third stage washers. It was indicated that a fourth stage washer would be needed for satisfactorily cleaning of the spent liquor from the pulp and that washer aid chemicals would improve the drainage of the stock without foaming being a problem. Although pulp production off the washers averaged a washing rate of 2.1 ODMT/sq.m./day, by the end of the run the rate reached 3.5 ODMT/sq.m./day and it was predicted that the rate could be raised to 7 ODMT/sq.m./day for whole stalk kenaf compared to a normal operating washing rate for these

units on pine pulp of 11.2 ODMT/sq. m./day. It was claimed that the decker handled the washed kenaf stock at a rate of 8.4 ODMT/sq. m./day. These measured and anticipated washing rates for whole stalk kenaf pulp are much higher than other investigators have reported. It is very questionable that they could be reached in commercial practice with a three- or four-stage system where low residual spent liquor solids in the washed pulp and a low dilution ratio of the spent liquor are required.

At Hudson, an attempt was made to run the unbleached kenaf whole stalk pulp over a Flakt pulp dryer with a cylinder mold wet end. The slow drainage of the pulp and foam prevented formation of a thick sheet on the cylinder and this, together with the long draw between the cylinder mold and the press section, made it impossible to transfer the web to the drying section. Finally, by adding 40 to 60 percent pine to the kenaf pulp furnish, it was possible to produce bales of dried pulp. This mixed pulp was later repulped and the kenaf portion was 22 percent of a furnish with unbleached pine pulp for a machine run of lightweight kraft paper. It was found that the refining of the mixed pulp could be reduced as compared to a 100 percent pine furnish and it was observed that the sheet appeared to dry more readily in the drying section. Because of the time and material limitations for the trial, the results of tests for strength properties were not subject to rigid interpretation. It was stated that the only valid conclusions appeared to be limited to the fact that kenaf whole stalk pulp has a much slower drainage than pine pulp at the same freeness level and that to develop required strength properties through refining of the mixed pulp would result in a reduction in machine speed or papermachine wet end modification to compensate for the reduction in drainage.

It was concluded that for the Hudson mill, based on these tests, there would be the following negative factors:

- (a) The yield per digester of kenaf whole stalk pulp cooked would be about half that of pine and hardwood;
- (b) Kenaf whole stalk would require 10 to 25 percent more active alkali per ton of pulp than pine pulp;
- (c) Batch digester load and cap time compared to wood pulp would be doubled;
- (d) Digester steam requirements per ton of pulp would be doubled;

- (e) Weak black liquor volume would be increased by 50 percent at lower liquor solids content for kenaf whole stalk pulp and because of this the evaporator steam requirements would be increased sixty percent;
- (f) By-product credits for turpentine and tall oil would be eliminated;
- (g) Washer production rate would be about 70 percent that for pine.

It was concluded that, with equal equipment operating parameters in the mill for kenaf whole stalk pulp and pine sulfate pulp, the cost of slush kenaf pulp would be about 90 percent the standard cost for pine pulp under the fibrous raw material cost situation prevailing at that time. However, Guttry (21) admitted that this could not be done with existing equipment and that costly additional capacity and major modifications would be required at all points in the pulp preparation process.

Uhr (29,30) has also discussed these same mill trials at Hudson and gave laboratory beater strength test data on kenaf whole stalk pulp compared to data for pine and hardwood pulps. He mentioned the need for making experimental kenaf pulps in the continuous pulping equipment that has been widely used for other nonwood plant fibers. In spite of the problems in pulping kenaf, he was optimistic about the future potential of kenaf for paper pulp where there would be limited supplies of wood.

2.6.4.10. Study of Kenaf Pulps for Papermaking at the Herty Foundation

It has been reported (96) that the Herty Foundation in Georgia was given a US\$100,545 contract in 1970 for a 3.5 year study of bleached kenaf paper pulp for printing and writing papers. The study was to be administered by the USDA's Agricultural Research Service. Methods were to be studied for separating kenaf bark, pith, core, and juice and pulping and bleaching tests were to be carried out under industrial conditions. It was proposed to produce at least 227 kg. of white bond paper from both green and field dried kenaf. Apparently, the purpose of this investigation was to verify and expand the pilot plant papermaking studies on kenaf by the USDA in 1969/1970, as described by Clark and coworkers (62,63). Unfortunately, the report on this work has not been published or made available for purposes of this review.

2.6.4.11. Kenaf Whole Stalk Chemimechanical Pulp
Developed by Champion Papers, Inc..

Champion Papers, Inc., has patented (98) a process for the preparation of kenaf whole stalk cold sulfite chemimechanical bleached groundwood for printing papers. Green and field dried kenaf whole stalks were used in the investigations and the process was found to be very advantageous when used on the field dried material. The field dried chopped kenaf that had been stored in a pile for 7 months was screened on a 3 mm. opening screen to remove dirt and other extraneous material. It was then treated with an aqueous solution of sodium sulfite and sodium carbonate at a pH of 10 to 11 for 1 to 30 minutes. The substitution of sodium hydroxide (cold soda pulping) for sodium carbonate gave dark colored, hard pulp sheets as compared to the soft and bulky pulp of this invention. After soaking the kenaf, it was pressed in a screw extruder to remove the soaking solution and to crush the fibrous material to make it suitable to feed to two stage double-disc refiners. It was also found that the soaking with the sulfite solution could be done after the crushing step but before the refiners. After refining, the pulp was washed to remove the residual chemicals and it was then bleached to as high as 71 percent GE brightness with 5 percent sodium peroxide in solution. It was found that, if the chemical treatment was not used before refining, the pulp had so much chop and so little fibrillation that it was difficult to form a suitable handsheet for testing. It was pointed out that kenaf whole stalk gives a beneficial and unique combination of fibers for the production of chemimechanical pulp because the bast fibers contribute desirable physical strength properties and the woody core material contributes to the opacity and light scatter coefficient of the pulp.

Recently, Lawrence (99) had advised that the work at Champion Papers, Inc., indicated that the kenaf whole stalk chemimechanical pulp would have superior papermaking qualities to those of a mechanical pulp made from the woody core material which constituted 70 percent of the stalk dry material in their tests.

2.6.4.12. Pilot Plant Papermaking Trials with Kenaf
Pulp at Eastman Kodak Co.

In parallel with the research being conducted by the USDA Northern Regional Research Laboratory, Crouse (100,101,102) has conducted an extensive investigation of kenaf growing, pulping, and papermaking under a grant from the National Science Foundation.

Two plots of H. cannabinus were grown, one in North Carolina with the entire plant above ground chopped with an ensilage cutter and one in New Jersey where the stalk was detopped prior to chopping. The Agronomy Department at the North Carolina State University at Raleigh assisted in the growing of the kenaf in that State. The kenaf was allowed to be frost killed before harvesting and chopping was carried out within four weeks after that. Chemical analyses of the total carbohydrate showed a high pentosan content and there were no significant differences in the two materials due to geographic location.

The kraft pulping trials were made at the State University of New York College of Environmental Science and Forestry at Syracuse where it was found that, because of the low bulk density (80 to 150 kg./cu.m.) of the chopped kenaf whole stalk, a liquid to solids ratio of 14:1 had to be used in the digester to insure complete wetting of the fibrous raw material. It was also found that the strength of the resultant pulp was somewhat adversely affected by the foliage and stem tops which had been left in the chopped kenaf.

For the papermaking trials, a specific grade of paper to be produced on the pilot plant paper machine at Eastman Kodak Co. was chosen in order to utilize the known favorable characteristics of kenaf whole stalk chemical pulp. This was the photocomposition lithography plate grade requiring low porosity and high surface smoothness. A blend of unbleached kenaf pulp with hardwood and softwood pulps was used in producing this grade of paper in comparison to the hardwood and softwood blend regularly used. Although there was a physical strength loss because of the particular blend used, at other than optimum for kenaf, the expected improvements in the required characteristics of porosity and smoothness resulted. It was shown that kenaf whole stalk sulfate pulp would be superior to hardwood sulfate pulp for use in the grade of paper made.

2.6.4.13. Adverse Comment on the Use of Kenaf for
Paper Pulp by Some Companies and Research
Institutions in the United States.

A recent publication (103) has mentioned an adverse evaluation of kenaf for paper pulp by a number of paper companies and one forestry research laboratory in the United States. A representative of one company (St. Regis Paper Co.) stated that only the bast fiber can be

used to make paper so that kenaf would be at a great disadvantage in comparison to softwoods where they can be grown. Another company, Bemis Co., has sold its kenaf operation (for textile bags) in Nicaragua because of the problems of growing and harvesting the kenaf. A spokesman from the Forestry Department of North Carolina State University at Raleigh stated he has given up trying to grow kenaf because the production is not that outstanding, presumably in comparison with the fast growing coniferous trees he has developed. On the other hand, Clark of the USDA answered these arguments by listing the well known factors which favor kenaf for paper pulp, particularly when the whole stalk can be utilized.

The Consultants recognize the basis for the arguments against the use of kenaf being predominantly the prevailing fiber supply and cost situation in the United States today. However, the adverse comments answered by this explanation become almost meaningless when applied to the situation in developing nations lacking traditional wood supplies or the possibilities for developing them within the necessary time and agricultural frames. In the case of the Mekong Basin, where kenaf is already a large established crop based upon the availability of low cost labor and land that is not more valuable for or capable of raising other crops, its use for paper pulp has a much greater potential for economic viability and for serving the national interests than in the United States and other major pulp producing countries where kenaf could be grown.

2.6.5. Work on Kenaf Paper Pulp in Nations Bordering on the Western Pacific Ocean

2.6.5.1. Studies on Growing and Pulping Kenaf by the CSIRO in Australia

According to Wood (104), field studies on the growing of kenaf for paper pulp started by the Commonwealth Scientific and Industrial Research Organization (CSIRO) at the end of 1972. It was judged that kenaf (*H. cannabinus*) could be grown on a year-round basis, under irrigation, at the Kimberley Research Station in the Ord Irrigation Area of Northern Australia. He reported that subsequent pulping trials at the CSIRO Forest Products Laboratory in Melbourne indicated that plant population, and method and time of planting did not affect pulp quality. However, date of harvest was found to be an important

factor because toward maturity a "corky" layer appears to form on the bark surface of the kenaf stalk and markedly affects the drainage characteristics of the pulp. Studies of this phenomenon were to be continued.

Wood and Angus (105) summarized information on all the soft, hard, and miscellaneous fibers that could possibly be considered for crop tests in Northern Australia. Kenaf was chosen as the one with the greatest potential for paper pulp. Consideration was given to harvesting the whole stalks of kenaf with sugar cane single row harvesting equipment which cuts and discards the tops and chops the stem into small billets. It was believed that reducing the billets to chips would be required for bulk handling and transport to Japan in competition with eucalyptus chips. A budget estimate was made of the cost of growing and harvesting kenaf for chips for export that indicated a reasonable chance for economic viability if the kenaf growing and harvesting were mechanized.

As a result of pulping studies by the CSIRO, further favorable comment on kenaf for paper pulp has been made by Wood (106). Separation of the two fractions for separate pulping by the soda process was indicated and the bast ribbon fraction was reported to be 35 to 40 percent of the dry stem weight. The ratio of bark to wood was found to be inversely related to growth rate and is highest in the dry season when growth is slowest. It was pointed out that the relatively low lignin content (9 to 10 percent) in the bast ribbon of the stalk requires such a mild pulping process that bleaching techniques only may be sufficient to remove the lignin and thus reduce processing costs. The suggestion was made that surplus woody core material be used for particleboards because of a favorable low basic density (0.13 to 0.25 g./cc.) of the raw material for this type of product. On the reverse side of this, the high freight cost to export such a low density material as kenaf was pointed out even though for papermaking fiber content the whole stalk kenaf chips would be worth US\$38.00/ODMT FOB when compared to eucalypt chips destined for Japan. This would of course favor the exportation of pulp or finished paper from kenaf grown in Australia.

Another CSIRO report was published by Wood and Angus (107) in which it was anticipated the technology of growing and harvesting kenaf for paper pulp would correspond to the highly mechanized systems used for sugar cane. This was estimated to make it possible for kenaf whole stalk for fiber for pulp to compete pricewise with eucalypt chips at the pulp mill level in Australia.

A news item (108) has mentioned studies by the CSIRO for producing newsprint from kenaf. Experimental tests indicated that newsprint from kenaf would be less porous than normal newsprint and would probably require a more costly ink and drying equipment for the ink on the printing press.

Detailed and extensive pulping studies on kenaf have been published by Watson, Davies, and Gartside (78) of CSIRO. They found that crushing the green stalk in sugar cane rollers gave a protein-rich juice and facilitated separation of the bast ribbon and woody core material for separate processing. The removal of the juice also reduced the chemical demand in pulping. Separation of the bast ribbon and woody core material for the various samples at different planting concentrations showed an average bast:core ratio of 35:65 based on dry weight of stalks. The pulping trials by the soda process showed the higher (20 percent active alkali) or more severe cooking liquor requirement for the woody core material compared to that (15 percent) for the bast ribbon. It was concluded that planting procedures and time of planting and cropping did not affect the pulping results. Unbleached pulp digester yields for the various samples ranged 43.9 to 60.3 (av. 50.8) percent for the bast ribbon samples and 42.6 to 49.6 (av. 45.7) percent for the woody core material.

In this investigation (78) by CSIRO, a process being patented has been discovered for separation of the kenaf bark (bast ribbon) and the wood (core material) fractions in conjunction with the extraction of the juices by pressing the green stalks in a sugar cane roller mill. In this processing step the bast ribbon comes from the rollers as a stringy fibrous mass while the woody core material is reduced to a particulate form. The two are readily separated by sieving and are thus suitably prepared for pulping separately. The pulping chemical requirement was reduced by pressing the juice out of the kenaf and the resultant pulp also had improved drainage characteristics probably due to the removal of some of the parenchyma cells, which cause slow drainage, along with the juices. Some comparative curves of the drainage rates at various levels of freeness were developed for softwood, hardwood, kenaf bark, and kenaf wood pulps.

Samples of the crushed bark fraction of kenaf stalks were used to prepare sulfate (kraft), soda, neutral sulfite (NSSC), cold soda, and mechanical pulps. Kenaf pulps were also prepared from the crushed wood fraction by the kraft, soda, and NSSC processes. The kenaf bast ribbon chemical pulps had excellent strength properties with the NSSC pulps having the best drainage properties.

Examination of the fibers of the pulps from both bast ribbon and woody core material showed small cellular particles attached to these fibers. Beating dislodges these particles and gives rise to the slow draining pulps, far out of proportion to the amount of actual refining done on the fibers. Washing and screening techniques were found to be quite effective in removing these parenchyma cells with respect to bast ribbon pulp, but when applied to pulps from the woody core material there was a heavy resultant loss of paper making fiber.

2.6.5.2. Kenaf Pulping Studies by Oji Paper Company in Japan

Although there has apparently been considerable interest in the pulping of kenaf by various Japanese companies, much of the data remain unavailable. However, Nagasawa and Yamamoto (114) of the Oji Paper Company have published the results of some of their investigations on growing and pulping the whole stalks of both H. cannabinus and H. sabdariffa.

In addition, kenaf cultivated in Florida was separated into bast ribbon and woody core material fractions for separate pulping trials.

Under moderate cooking conditions the kenaf whole stalk pulp yield was 48 percent across the digester. The full chemical pulps were found to have lower initial freeness values than for hardwoods pulped commercially in Japan. The kenaf pulps were blended with or compared with wood pulps in trials on an experimental paper machine.

Compared to paper from unbleached softwood sulfate pulp, the paper made from kenaf whole stalk unbleached sulfate pulp alone showed slightly higher bursting and tensile strength, lower tearing strength, and much lower air porosity and sheet toughness values. It was judged that the kenaf whole stalk sulfate pulp would not be able to withstand any appreciable refining if it were used in pulp furnish blends for the manufacture of cement sack paper in view of the comparatively low energy absorption (as represented by a low toughness value) and the reduced porosity of the sheet for the passage of air that quickly develops with the least bit of mechanical action on the pulp.

When compared to printing paper made from a 100 percent hardwood bleached sulfate pulp furnish, the paper made from 100 percent kenaf whole stalk sulfate pulp showed improved physical strength properties although the kenaf paper had lower opacity and surface smoothness. Printing tests of the fine paper made from blends with hardwood or 100 percent kenaf whole stalk bleached sulfate pulp were quite

satisfactory under normal papermaking procedures using clay filler for opacity and the size press (apparently with a starch solution) for surface improvement.

The study by Nagasawa and Yamamoto (114) on producing refiner mechanical pulps from kenaf whole stalk, bast ribbon, and woody core fraction was made in comparison with the hardwoods used commercially in Japan for this type of pulp. The physical strength characteristics for the kenaf bast ribbon mechanical pulp were very high compared to the hardwood and other kenaf pulps. For mechanical pulp made from kenaf whole stalk and blended 40 percent in papermaking furnish with wood pulps for newsprint, there was a slight reduction in ink transfer to the sheet in laboratory printing trials but the printed opacity was increased by increasing the kenaf portion of the furnish. It was concluded that kenaf whole stalk mechanical pulp would be excellent for manufacturing newsprint but that there might be a disadvantageous factor due to the fine fiber and debris from the woody core portion of the stem causing two-sidedness of the newsprint produced from it on a commercial paper machine.

2.6.5.3. Developments on Kenaf for Paper Pulp by Toyo Pulp Company

Hanaya (77) of Toyo Pulp Company has reported that this company is developing a kenaf bast ribboning machine with automatic feeding apparatus. In a study of transporting the various available fibrous raw materials to Japan, Hanaya (115) has pointed to the low density of the nonwood plants when in bulk storage (60 to 70 OD kg./cu.m.) compared to softwood chips (160 to 190 OD kg./cu.m.) or hardwood chips (210 to 336 OD kg./cu.m.) in the hold of a chip ship. For press packed bales of nonwood plant raw materials the density of 140 to 160 OD kg./cu.m. was reported compared to 230 to 250 OD kg./cu.m. for softwood logs and 276 to 440 OD kg./cu.m. for hardwood logs. The bulk densities reported for baled nonwood plant fibers by Hanaya are much lower than reported for kenaf in the agro-economic sections of this Study.

Although this company has not made any information available for review in this report, it appears that they have done development work on kenaf for paper pulp and have developed a pilot plant that could be used for further studies.

2.6.6. Studies on Kenaf for Paper Pulp in Europe and West Asia

2.6.6.1. The Growing and Pulping of Kenaf by FaBoCart, S A. in Italy

An extensive investigation, starting in 1974, of kenaf for paper pulp has been described by Canesi and Ruffini (109) for FaBoCart, S.A. of Italy in a report on their heretofore unpublished studies. Studies on growing kenaf have been carried out in plots in northern and southern Italy. Trials have been made and are continuing using different cultivation techniques and new varieties of kenaf. Extensive laboratory work under Dr. Ruffini's direction has resulted in the preparation of a full range of kenaf pulps for test production of cultural papers from newsprint to coated printing grades. In addition to utilization of the whole stalk, technical investigations have also been carried out on the bast ribbon and woody core material fractions of the stalk.

Data furnished on these pulps indicate that they have produced both mechanical and cold soda kenaf whole stalk pulps with potential for industrial application in the manufacture of newsprint and ground-wood-containing type papers of all grades. Full chemical soda pulp at a 48 percent unbleached digester yield for 15.3 percent consumption of sodium hydroxide had strength properties considered average for kenaf whole stalk pulps of this type. In addition, preliminary paper machine trials have been made in which kenaf pulps were used as partial substitutes in standard furnishes for various grades of paper.

It is interesting to note that these investigators point out that their major problem now is to find systems that will result in lower costs for harvesting and transporting the kenaf.

2.6.6.2. Research on the Use of Kenaf Scutch for Pulp in the U.S.S.R.

Morgen (116) has reported that the harvest of kenaf in the Tashkent district and the separation of the bast fiber leaves a large quantity of kenaf scutch (woody core material) that could be utilized for paper manufacture or cellulose chemical products. Samples of kenaf core material were analyzed. Experimental pulp for cellulose acetate for lacquers was prepared by prehydrolysis, soda pulping, and bleaching.

2.6.6.3. The Manufacture of Cigarette Paper from Kenaf in Yugoslavia

In Yugoslavia, the Tvornica Papira Rijeka mill has been producing high quality cigarette papers for more than three years from kenaf. Benko (120) has reported this mill as being the only one in the world where decorticated kenaf ribbon containing about 15 percent woody core material has replaced the more expensive classical raw materials, hemp and flax wastes, for this grade of paper. In the last year, consumption of kenaf exceeded 2,000 tons. Digestion is by a polysulfide cooking process with a yield of about 50 percent bleached pulp. The pulp requires more time and energy in beating than the raw materials previously used. The alpha-cellulose in the pulp is 90 to 92 percent and this was said to be an important factor in uniform burning of the cigarettes.

2.6.6.4. Studies on Kenaf Paper Pulp at Ecole Francaise de Papeterie

A communication from Noel (112) of this institution has advised that some laboratory investigations on pulping kenaf were made for an industrial client about 15 years ago. The results were not published and the information is not for release at the present time.

2.6.6.5. Work on Kenaf Paper Pulp in France by Le Centre Technique de l'Industrie Papetiere

Bouchayer (110) has stated that the work of this laboratory started on kenaf for paper pulp in comparison with sorghum, Provence reeds, and hemp in 1962. Although some general results of these studies were eventually published, the detailed reports were documents for internal use by the organization. The final conclusion was that kenaf was not a suitable crop for the area in France due to the risk involved in having to import all the seed because the plant would not ripen under local conditions.

In their screening work to find a suitable crop that could be grown in France for a source of fibrous raw material for paper pulp, Bouchayer, Pujol, and Bernard (111) made pulping evaluations of whole stalk hemp, sorghum, whole stalk kenaf, and Provence reeds. They reported that l'Institute Agronomique de Montpellier had been able to

obtain only about half the high yields for kenaf that had been reported for the United States and that on this basis the fiber became quite costly. Also, the failure of kenaf to reach maturity under the growing conditions in France required importation of all seeds for the crop.

Although they (111) obtained pulp yields across the digester as high as 42 percent for the kenaf whole stalk, they recognized that this pulp contained a large percentage of fines that would be disadvantageous in papermaking. In general, they found that removing about 15 to 20 percent of the fines from the pulp by treatment in a Celleco fractionator improved the drainage characteristics and bleachability. Although the tearing and tensile strengths were greatly improved by removal of the fines, it was found that storage of the material for a year under biological conditions which retted the fiber resulted in a very drastic loss of pulp physical strength properties. Because of these factors and the high cost of producing the kenaf, it was concluded that the Provence reeds would be the most suitable crop of non-wood plant fibrous raw material for paper pulp in France.

In 1969, a brief note (122) was published on earlier reports (123,125) on the agro-economic aspects of these studies and the drawbacks to raising and pulping kenaf in France. The low yield of bleached pulp of 32 to 35 percent due to the desirability of removing fines from the pulp was emphasized and it was again judged this source of fibrous raw material would not be practical or economical under the conditions existing in France.

Although the Institut de Recherches du Coton et des Textiles Exotiques (IRCT) has been supporting studies in the tropics on the agricultural aspects of kenaf, they had been following the pulping work at the Centre Technique de l'Industrie Papetiere. Their unfavorable conclusions about kenaf for paper pulp were the same as held by others who carried on these investigations in France.

2.6.6.6. Report on Kenaf Pulping Studies at Cellulose d'Aquitaine

Preliminary pulping tests on kenaf in France were reported at the February 1969 TAPPI meeting by Garnache (113) of the St. Gaudens mill of this company. Kenaf for the pulping trials was grown by the Agronomic Research Center (INRA) near Montpellier. In chipping the kenaf in a 12-knife Carthage chipper, uniform chips were not obtained.

The chips consisted of about 56 percent small chips, 30 percent bark (long fibered material) and 14 percent pith and other parenchymous small particles. Cooking trials indicated that the whole stalk would be cooked satisfactorily with 20 percent NaOH at lower temperature and pressure than used. Unbleached pulp yields across the digester were 46.5 percent. Using the CEDED bleaching sequence, a total of 7.3 percent active chlorine was used to reach 89 percent brightness and a final yield of 42.5 percent bleached pulp. Although pulp physical strength properties were comparable to those for hardwoods, the low initial freeness of the kenaf pulp was said to raise the problem of fines removal.

Because of the importance of this aspect of making a satisfactory pulp from whole stalk kenaf, Garnache (113) has reviewed and given additional details on the work done at the Centre Technique de l'Industrie des Papiers, Cartons et Celluloses by Bouchayer, Pujol, and Bernard (111) on fines removal. The aim of these experiments was to find out to what extent fines removal either before or after pulping would (a) increase initial freeness and mechanical strength of the pulp, (b) improve delignification, and (c) lower the yield. In the process for wet cleaning and depithing the chips were gently crushed in a laboratory grinder dry and then wet and further broken down to particles 5 to 10 mm. in size. This product was then screened with running water on a three stage sieve of 8, 14, and 17⁰ mesh screens retaining 68.5, 1.0, and 6.5 percent respectively of the original dry material with a loss of 24 percent through the third screen. In the pulping tests great care was taken to minimize fiber losses from the original kenaf and the 8 mesh fraction. It was found, using comparable cooking conditions, that the kenaf whole stalk first fraction from which 31.5 percent of the fines and water solubles had been removed by wet cleaning had a much lower permanganate number of 11 than the 18 the original material had when pulped without wet cleaning. (Consultants' note: Obviously the former was drastically overcooked resulting in adverse effects on the resultant pulp strength properties.) The wet cleaning resulted in only a minor increase in initial freeness of the pulp, the strength properties were lowered in all categories (obviously due to overcooking), and the unbleached pulp yield based on the original whole kenaf stalk was decreased to 33 percent from 39.7 percent. It was concluded that this procedure for fiber preparation would not be interesting for a commercial process.

In the second procedure described by Garnache (113), a Celleco Fractionator was used to remove fines from unbleached whole stalk kenaf pulp that had had no pretreatment of the raw fiber before the digester. Removal of 7, 16, and 32 percent of the kenaf fibers lowered the unbleached pulp yield based on original material from 41.5 percent to 38.5, 35, and 28 percent respectively. Fines removal raised the initial freeness value from 275 ml. C.S.F. for the whole pulp to 280, 420, and 480 respectively. Compared to the initial permanganate number of 13.8, the resultant values were 11.7, 10.9, and 8.4 for the corresponding stages of pulp after fines removal. The tearing and folding strength properties of the unrefined pulps were increased by the fines removal with other strength properties remaining essentially the same. It appeared that optimum results for pulp strength properties were achieved at about 20 percent fines removal.

Garnache (113) concluded that kenaf can be easily pulped and bleached by normal processes used for various woods. Although the kenaf whole stalk bleached pulp was judged to be better in mechanical and optical properties than birch pulp, the yield was lower and the low initial freeness was said to cause a drawback in paper manufacture unless kenaf were blended at less than 20 percent of the furnish with wood pulp. Because of the drainage problem with the fines in kenaf pulp and the higher area yield of fibrous raw material (almost twice that for kenaf) from Provence reeds (*Arundo donax*), the latter plant was chosen as being more suitable for agricultural development for paper pulp than whole stalk kenaf in France.

2.6.7: Investigations on Kenaf for Paper Pulp in Latin America

2.6.7.1. Chemical Cellulose Pulps from Kenaf Produced in Cuba

The work on preparing cellulose for acetylation that has been done in Cuba at The Cuban Sugar Cane Derivatives Research Institute (ICIDCA) has been described by Triana (117). The pulps were prepared from prehydrolysis-sulfate and nitric acid digestion processes. Photomicrographs published illustrate kenaf and other fibers before and after the chemical pulping processes.

2.6.7.2. Studies in Mexico on Kenaf for Paper Pulp

One of the early studies on kenaf for paper pulp was reported in 1959 and published in Mexico in 1961 by Carrasco and Vigna (118) of the Laboratories Nacionales de Fomento Industrial where earlier studies had been carried out by Olmedo (119) prior to 1957. Chemical and physical analyses of the kenaf fiber (apparently retted fiber) were compared to those for yuccas, henequen decortivating waste, bamboo, depithed bagasse, hardwoods, and softwoods.

Sulfate pulps were prepared from the kenaf bast fiber using 9.0, 12.0, 15.0, and 18 percent active alkali with digester yields of 70.6, 66.4, 64.3, and 63.7 percent of unbleached pulps correspondingly attained. The kenaf bast fiber pulps were much stronger than sulfate pulps from the other fibrous raw materials tested, including the softwood, Pinus ponderosa. The physical strength properties of the kenaf fiber pulps and cooking yields were higher than those of the other fibrous raw materials tested. The kenaf bast pulp was found to be more easily bleached and stronger than pulps that would be produced from softwood.

2.6.7.3. Investigations on Growing and Pulping Kenaf in Argentina

The work in Argentina on kenaf for paper pulp has been described by Ordóñez and Zilli (121). The Department of Forestry started some experimental plantations of kenaf and several varieties were grown in three parts of the country where climates and soils are quite different and field yields were determined. Chemical and fiber properties of the kenaf stalk material were measured and an inorganic analysis was also made. Difficulties in getting representative samples of the whole stalk for pulping occurred in cutting them into 4 to 5 cm. pieces due to separation of the green stalk fiber components. Although the bast ribbon was found to be only 20 percent of the volume of the stalk, it was 30 to 40 percent by weight of the dry content for the various samples. Extensive pulping trials were made under a wide range of cooking conditions on samples of green kenaf which had been stored in the refrigerator for six months. Digester pulp yields varied from 34.2 to 45.8 for Kappa numbers ranging from 13 to 37. The necessity for high liquor ratios to get uniformity in cooking kenaf was pointed out. The strength and physical properties of the whole stalk kenaf sulfate pulps were compared with a pine softwood pulp and eucalyptus. The data showed that the kenaf whole stalk sulfate pulp was closer to pine sulfate pulp in physical strength

properties than eucalyptus sulfate pulp. However, the abnormally high air resistance of the kenaf pulp handsheets compared to those from pine pulp at relatively low sheet densities of the handsheets was very apparent from the data.

In the comparison of the sulfate versus the soda cooking processes, the data showed that the increase in sulfidity of cooking liquor up to 10 percent increased the velocity of pulping but beyond that the higher sulfidities resulted only in increased pulp yields. The physical strength properties of the pulps were comparable for the two chemical processes of pulping. Bleaching trials using the CEHEH sequence were found to give satisfactory pulps of 84/86 percent brightness without physical strength losses. Chlorine dioxide or peroxide bleaching stages were not required to reach this high brightness level for kenaf as is required in the case of wood pulps.

Because of the stronger pulp that results from cooking bast ribbon, these investigators have considered trying to fractionate the whole stalk components before pulping or the mixed fiber pulp after the digester. They recognized that the former procedure would allow optimum pulping of the two fractions with separate cooking. With 14 percent active alkali, the unbleached bast ribbon pulp yield of 56.8 percent at 21 Kappa number was obtained. The woody core material required 19 percent active alkali to reach a Kappa number of 19 at 42 percent yield. The initial freeness of the bast ribbon pulp was 13° S.-R. (760 ml. CSF) as compared to the much slower draining woody core material pulp at 35° S.-R. (360 ml. CSF). As found by other investigators, the bast ribbon pulp had far better drainage characteristics and was more nearly equal to pine softwood sulfate pulp in physical properties than the whole stalk pulp at all levels of refining in laboratory testing.

For fractionation after pulping, a kenaf whole stalk sulfate pulp was classified in the H.S. Fractionator on a laboratory test 7 mesh/cm. screen. The results of the fractionating procedure were very impressive and the data at initial conditions before refining are as follows:

<u>Test Item</u>	<u>Original Whole Stalk Pulp</u>	<u>Pulp Fraction Retained 7 Mesh Screen</u>	<u>Pulp Fraction Passing 7 Mesh Screen</u>
Amount (% Dry Basis)	-	45.5	54.5
Freeness (° S.-R.)	36	17	53
(Equivalent ml. CSF)	350	660	190
Tensile (m.)	11,200	3,400	12,700
Burst Factor	64	18	72
Tear Factor	116	277	55
Density (g./cu.cm.)	0.56	0.34	0.81
Stretch (%)	2.6	1.4	2.8
Air Resistance (Sec. per 100 ml.)	310	0	10,000

These data do not truly show the differences in physical properties between kenaf bast ribbon and whole stalk pulps cooked separately. They do show the extreme differences in physical properties resulting from separating all the long bast pulp fibers in one fraction and all the short fibers, parenchyma cells, debris, etc. of the whole stalk after cooking in another fraction. From these data it is quite obvious that any refining of (or even incidental mechanical action on) the kenaf whole stalk pulp to develop tensile or bursting strength from the bast fraction of the pulp would result in a further undesirable deterioration of the drainage characteristics. This would be due to the behavior of the woody core fraction pulp as a highly beaten pulp when there has been no refining at all of the pulp. It is indicated from these data, as from that from many other sources, that kenaf whole stalk pulp will not require any refining in the paper mill for most grades of paper and will have to be mixed with other pulps in the furnish after they have been refined for their optimum strength development.

In general, these investigators concluded that kenaf whole stalk pulps have excellent physical strength properties but poor porosity. The bleached kenaf chemical pulps were between pine softwood and eucalypt sulfate pulps in opacity. It was also recognized that further investigation of means to separate the two types of fiber would be of great importance and that the special problems in cooking, washing, and recovery of the spent pulping liquors would have to be given full consideration in the choice of equipment for a pulp mill.

2.6.8. Development of Kenaf Paper Pulps in Nations Bordering on the Indian Ocean

2.6.8.1. Studies on Kenaf Pulping in Bangladesh at Eastern Regional Laboratories

Evaluation of mesta (H. sabdariffa) (South Asian Kenaf) for paper pulp was carried out at the Eastern Regional Laboratories (P.C.S.I.R.) in Dacca, now Bangladesh. A report has been published on these investigations by Islam, Khan, Maisan, and Khan (126). Because of the availability of mesta waste materials, the studies were concerned with the dried woody core material (mesta stick) left after retting of the stalk and removal of the bast fiber.

The data reported cover chemical analyses of the raw material and fiber dimensional analyses which showed the mesta stick pulp to have longer fibers than pulp from jute sticks. Both soda and sulfate pulps were prepared using 20 to 24 percent cooking chemicals with the optimum unbleached pulp yield found to be 48 percent. Bleaching trials resulted in pulps at 44 percent yield of 74 percent brightness by the CEH sequence and 84 percent by the CED process. Samples of printing and writing papers were successfully made on a pilot plant paper machine using bamboo chemical pulp as the long fiber component of the pulp furnish.

2.6.8.2. Kenaf Pulping Studies in Pakistan by Packages, Ltd.

Toor and Mubin-ud-Din (127) made comparative chemical and pulping evaluations of a wide range of fibrous raw materials that were in use or being considered for paper pulp in Pakistan. The nonwood plant fibers were pulped by the full chemical neutral sulfite process and crude pulp yields across the digester of 49 to 56 percent were obtained for kenaf whole stalks. It was concluded that kenaf would command the greatest interest for the nonwood plant fibers as a fibrous raw material for paper pulp to replace imported wood pulps.

2.6.8.3. Commercial Production of Kenaf Pulp in India

There have been rumors that a number of mills in India have at various times pulped whole stalk kenaf or the woody core material but no historical data has been obtained for this Study on actual commercial production.

2.6.8.4. Studies in India on Kenaf Pulping at J.K. Paper Mills

Pathak, Kumar, Jivendra, and Jain (128) have discussed the various agronomic aspects of kenaf and the harvesting and storage of the whole stalks for paper pulp. Chemical analyses of the fibrous raw materials and pulping and bleaching trials were made in comparison of kenaf with bamboo and eucalyptus. In general, the unbleached pulp yields were 49 percent for kenaf whole stalks, 44 percent for bamboo and 40 percent for eucalyptus.

These authors (128) estimated the plantation area required to supply a pulp mill with kenaf. The storage area requirement for kenaf in bundles was estimated to be about twice that for bamboo. The cost of producing kenaf bleached paper pulp was estimated to be about 10 to 15 percent more than for the bamboo pulp.

2.6.8.5. Kenaf Pulping Investigations at Sirpur Paper Mills, Ltd. in India

Extensive laboratory studies on kenaf pulping in India have been reported on by Misra and Sarbacharyulu (129). They reported very low field production yields for the whole stalk kenaf produced for the experiments, although the thin stems contained about 35 percent bast ribbon component. Extensive comparison pulping and bleaching trials were made of whole stalk, retted bast fiber, and the woody core material left after the retting operation.

For the kenaf whole stalk pulps they (129) found that, at 16 percent active alkali, the unbleached sulfate pulp yield from the digester was 48 percent compared to 43 percent for soda pulp with a much lower pulp viscosity test. Bleached pulp yields were 40 and 34.4 percent respectively. It was also determined that the pulp physical strength properties and the fiber slenderness ratio for the unbleached sulfate pulp from whole stalks were higher than for soda pulp.

When these investigators (129) pulped the retted bast fiber at optimum conditions with 10 percent active alkali, a yield as high as 74 percent was obtained for sulfate pulp. Pulping by the soda process reduced the unbleached yield from bast fiber to 50 percent and resulted in lower unbleached pulp physical strength properties. It was also found that the sulfate bast fiber pulp could not be bleached higher

than 65 percent GE with a single hypochlorite stage, whereas the soda pulp bleached easily to 83 percent GE and had higher strength properties after bleaching than the sulfate pulp.

In the pulping trials (129) on kenaf woody core residue from the retting operation, 14 percent active alkali was required to produce a bleachable grade of pulp at an unbleached yield of 45 percent. The pulp yield shrinkage during bleaching was 15 percent, resulting in a final bleached pulp yield of 38 percent based on the woody core material after the retting process.

These authors (129) compared the parameters for manufacturing kenaf pulps with those for bamboo pulps and found the whole stalk kenaf pulp would (a) cause a 28 percent loss in productive capacity of the batch digester due to kenaf's low bulk density, (b) the cooking liquor dilution ratio for kenaf would be almost twice that for bamboo, resulting in larger evaporators and additional steam requirements in the recovery system, and (c) the kenaf would require 33 percent more active alkali than bamboo for pulping. In addition, it was judged that soda pulping would be unsuitable for bleachable grade kenaf whole stalk pulp and that the sulfate pulping process would be required. It was also determined that kenaf whole stalk sulfate pulp was more easily bleached than bamboo pulp and that in general the physical strength properties of the pulps were comparable.

In the case of the kenaf bast fiber pulps, the investigators (129) noted the low active alkali requirements for cooking. The unbleached sulfate pulps were found to be higher in yield and strength properties than soda pulps although it appears optimum strength soda pulps were not produced. The claim was also made that bleaching kenaf bast fiber pulp causes considerable loss in strength properties.

As for the pulps from kenaf core sticks, they were reported (129) as being very low in strength and the pulping of this material was judged to be uneconomical in terms of final yield and quality of bleached pulp.

In a study of tropical hardwood pulp at Sirpur Paper Mills, Ltd., Misra (130) has given brief comparative test data on bamboo and kenaf whole stalk pulps. Using a grading system with the pulping characteristics of bamboo as the standard of comparison, kenaf whole stalk was judged to be in the second choice group as a fibrous raw material for pulping.

2.6.8.6. Investigations on Kenaf Pulping at the Forest Research Institute in India

Guha (131) has reported on a hot soda pulping process developed for use on agricultural residues at the Indian Forest Research Institute at Dehra Dun. Pulping whole stalk kenaf for one hour at boiling temperature with 10 percent NaOH gave a 75 percent yield of chemimechanical pulp suitable for corrugating medium. Guha and Sharma (132) have supplied further data on pulping tests in this laboratory. In their investigations, the kenaf whole stalk sulfate pulp was found to have better physical strength properties than the soda pulp made under the same cooking conditions with 18 percent caustic soda at a yield of 44.5 percent. Samples of wrapping paper were made on a pilot plant paper machine and the kenaf whole stalk pulp was found to have good runnability. Bleaching of the pulp to 75 brightness on a CEH sequence with 10.4 percent available chlorine resulted in a final bleached pulp yield of 37.6 percent with a considerable loss in physical strength properties. Cold soda pulp at 79 percent yield and reasonable strength properties for that type of pulp was also prepared from whole stalk kenaf.

2.6.8.7. Pulping Studies on Kenaf at Indian Technological Research Laboratories

Jain and Bhowmick (133) have carried out laboratory pulping and bleaching studies on kenaf wood core residues from retting operations. The resultant kenaf pulps from the woody core material were inferior to pulp from jute sticks and, in addition, had very poor drainage characteristics.

2.6.8.8. Pulping of Kenaf for Chemical Cellulose Pulp at the Indian Jute Technical Research Laboratory

The Indian Council of Agricultural Research (134) has issued a report on the pulping of kenaf core residue from the retting process and its use to prepare cellulose nitrate for use in lacquer and celluloid.

2.6.8.9. The Production of Kenaf Pulp and Paper at the Eastern Paper Mills Corporation in Sri Lanka

From the information gathered from all available sources, it appears that Eastern Paper Mills Corporation in Sri Lanka has come the nearest to practical commercial use of kenaf for paper pulp at the present time. The initial press notices (135) reported that printing and writing papers made from a 50-50 furnish of bleached straw and kenaf pulp had higher strength properties than paper manufactured from 65 percent straw pulp and 35 percent imported wood pulp.

Jeyasingam (136) published the first technical notes on the commercial trials at Eastern Paper Mills. The kenaf field dried whole stalks were pulped in batch digesters with 19 percent caustic soda to a permanganate number range of 14 to 17 with an unbleached pulp yield of 48 percent. The cooking conditions were 0.5 hours to pressure and 3.5 hours on pressure at 170°C. The kenaf pulp was much easier to wash than rice straw pulp but there was considerable foaming. The filter rate on the vacuum washing system was estimated at 2.4 tons/sq.m./day compared to 1.59 for straw pulp. In attempting to screen the pulp, it was found that the 1.2 mm. diameter holes in the plates of the centrifugal screen were too small for this pulp although they were satisfactory for rice straw pulp. When operated on the kenaf whole stalk pulp, the screen rejected the entire portion of the longer bast fiber pulp and accepted only the pulp from the woody core material. Therefore, the screening system had to be by-passed. However, the final bleached kenaf pulp without screening was as free of shives as the straw pulp after screening and bleaching.

Bleaching of the pulp to 70° GE brightness in a two-stage hypochlorite batch bleaching system required a total of 8 percent available chlorine. A beneficial effect of using the kenaf was a 50 percent reduction in the size and alum used in the paper, even when the clay content of the paper made was raised to 20 percent from the standard 10 percent. The slow drainage on the paper machine wire of the kenaf pulp, as compared to that of the softwood pulp normally used with the rice straw pulp, was noted.

Further information on the problems encountered in growing, harvesting, transporting and pulping the kenaf whole stalk was published by Jeyasingam (137). Among them were complaints received from the men harvesting the kenaf that fine hairlike materials on the seed capsules caused skin irritation and that insects on the seeds also caused an unpleasant situation. The economics of growing kenaf in competition with rice were examined and it was found that the kenaf yield on land

suitable for growing rice would have to be 17.5 tons/ha. to give the farmer an equivalent annual income from his land. In comparison with the cost of softwoods which could be grown in plantations on land not suitable for rice, the yield of kenaf was also estimated to have to be this high for an equivalent return. Considering that, in preliminary agronomic trials in Sri Lanka on marginal agricultural lands not suitable for food crops, the yields of kenaf whole stalk (H. cannabinus) were only 3.75 to 5.0 tons/ha., the cost of kenaf on this basis would be too high in competition with plantation softwoods.

More detailed reports with additional information on the mill trial runs have been published by Manokeran and Cathirgamu of Eastern Paper Mills (32). A Nyblad cutter was found to be suitable for cutting the green or field dried kenaf stalks. However, whole stalks which had become wet in storage were hard to cut due to separation of the bast ribbon by the mechanical action of the cutter gripper rolls.

In addition to the bleached pulp for the printing and writing grades, unbleached pulp was used in a run of linerboard. In the bleached grade papers, where it was substituted for softwood pulp, the use of kenaf pulp improved the drying rate on the paper machine. The paper containing 50 percent of the kenaf pulp with straw pulp also had improved formation, smoothness, and dimensional stability, as compared to the standard grade using 65 percent straw pulp and 35 percent imported softwood pulp. However, laboratory beater tests on the pulp samples showed that using the two stage hypochlorite bleaching sequence had a considerable effect in lowering the pulp physical strength properties compared to the unbleached pulp.

Further studies on kenaf pulps at Eastern Paper Mills Corporation have been reported (138). High yield chemimechanical pulps were prepared by cooking field dried kenaf whole stalk chips at 100°C with 4 to 8 percent caustic soda for 3 hours and the cooked chips were mechanically defibered to get unbleached pulp yields of 55 to 62 percent. Bleaching with hypochlorite to 56 to 59 GE brightness gave a yellow coloration to the pulp. Bleachable grade sulfate pulp from kenaf was also prepared in the laboratory at a yield of 39.4 percent across the digester showing a lower yield than reported in their earlier investigations. It was concluded that 80 percent of the high yield chemimechanical or semichemical pulps from bamboo, sesbania, or kenaf whole stalk plus 20 percent full chemical bleached pulp from kenaf or cypress would provide a suitable fiber furnish for manufacturing newsprint.

Cathirgamu and Manokeran (139) have reported more recently on kenaf laboratory pulping studies at Eastern Paper Mills Corporation which started with growing kenaf (H. cannabinus) in 1967. The last season's crop of kenaf for seed on 80 ha. of land gave a yield of about 6.25 tons/ha. of whole stalk for paper pulp trials. Pulp production from kenaf in the mill was 24 tons in 1973, 100 tons in 1974, and about 500 tons in 1975. Soda pulps were produced with an unbleached pulp yield of about 50 percent on the average while monosulfite pulp gave a yield of 45 percent. The monosulfite pulp did not cause foaming on the washers as was the case for the soda pulps. Tests on the pulp in the washing system showed that the freeness of the stock off of the first washer drum was 26° S.-R. and off the third drum 18°. This indicates a removal of some of the fines from the pulp as the washing progresses. It was also suggested that using a screw press to deliquor the pulp ahead of the vacuum washers would improve the washing, give a higher concentration of liquor to the evaporators, and would give a freer pulp on the vacuum washers due to prior removal of fines during defibering of the woody core material in the pulp by the mechanical action of the screw press. The earlier problem of screening the kenaf pulp was also solved by using screen plates with 2 mm. diameter perforations rather than the 1.2 mm. diameter holes used for straw pulp.

In addition to the favorable behavior of kenaf pulp in the paper-making system, which was also described in previous publications, these authors have mentioned a few more observations. They found that, when field dried stalk bundles are stored without being covered, the kenaf became infected with fungus when it got wet. They stated that crushing the kenaf stalks to remove the green juices and baling the fiber would allow it to be stored and would reduce the chemical consumption in cooking.

In studies on refining the kenaf pulp for the paper machine, these investigators reported that kenaf whole stalk pulp consumes about one tenth the energy consumed by softwood pulp to reach an equivalent freeness level. Although the press section did not remove as much water from the paper web when kenaf pulp was used in the furnish to replace softwood pulp, the drying rate in the dryer section was considerably higher for the kenaf pulp furnish mixture.

2.6.9. Developmental Work on Kenaf Paper Pulps in Countries
Within the Mekong Basin Area

2.6.9.1. Introduction

In the initial survey of the abstracts of the world's technical literature on pulping kenaf, the Consultants did not find any indexed references indicating that investigations of this fibrous raw material for paper pulp had been or were being carried on in the Mekong Basin countries. Surprisingly, however, the field survey in Thailand determined that several research laboratories and companies in Thailand have been actively working in this field and that there are a number of important technical studies and other documents available for this review.

The field survey by the Consultants also found that there are a number of well-equipped pulp/paper laboratories in Thailand. In addition to the mill laboratory and pilot plant at the Siam Kraft Paper Company, Ltd., which includes pulping facilities and an experimental paper machine, there are reported to be three research laboratories for pulp and paper in Bangkok. One is at the Department of Science of the Ministry of Industry and this was established in 1964 as a UNDP/FAO Special Fund project. It has an experienced staff and excellent technical facilities and library. The Kasetsart University is reported to have a modern pulp/paper research laboratory established in the Forestry School. The Royal Department of Forestry also is reported to have a pulp and paper research laboratory established in 1968 with some technical personnel supported by UNIDO for research on paper pulp from various fibers for a number of years.

In addition to the research institutions working on kenaf, the Thailand Board of Investment (BOI) (140) has listed three pulp projects based on kenaf or kenaf waste the BOI has given preliminary approval for or granted Certificates of Promotional Privileges. The first of these projects was that of the United Pulp and Paper Co., Ltd., whose certificate was granted but has now expired. The second project for kenaf whole stalk pulp is that of Phoenix Pulp and Paper Co., Ltd. The third project is that of the Sri Ayudhya Pulp Co., Ltd., which has been reported as being planned to use kenaf waste along with several other nonwood plant fibers (bagasse, rice straw, corn-stalks and Kachornchob grass) for the fibrous raw material supply. Both of these projects have been approved for promotion by the BOI but at the time of the Consultants' field investigation there was no evidence that the certificates had been granted.

2.6.9.2. Investigations on Kenaf Pulping and Mill Feasibility
Studies in Connection with the United Pulp and Paper
Co., Ltd., Project

In the subsequent Section 6.2. of this Chapter I of this Study, the business project development history of the United Pulp and Paper Co., Ltd. (UPPC) (200,201,202,209) is reviewed with respect to the increase in planned mill productive capacity and investment requirement that occurred during the approximately five years of activity on the project before the BOI certificate expired in 1974. During this period at least two studies (201,183) were made for the UPPC project by Associated Consultants Co., Ltd., of Bangkok. The preliminary project study (201) was released to participants at the UNIDO conference on industrial promotion in Manila in 1970 and, based on further input from a number of equipment suppliers and research organizations, was updated in the feasibility study (183) which was widely circulated among consultants, international agencies, potential suppliers of equipment and services, investors, and others in the world's pulp and paper industry who were considered to be interested in helping to bring the project to implementation.

The feasibility study was based upon studies on kenaf pulping by the Applied Scientific Research Corporation of Thailand (ASRCT) and other research laboratories abroad. This report concentrated upon the economics, financing, and implementation of the project.

In this study (183), it was proposed that the pulp mill to be located on the Pasak River near Saraburi would be capable of producing 50,000 tpy. of fully bleached kenaf whole stalk chemical pulp or 40,000 tpy. of bleached pulp and 20,000 tpy. of unbleached grade. Based upon mill tests in 1970 in which pulp and paper were produced from kenaf whole stalks in the Thai Government's Bang Pa-In mill, it was recommended that the CEHH bleaching sequence would be satisfactory and that fibrous raw material used would be 2.6 FDMT/ADMT of bleached pulp product. This would be equivalent to about a 40 percent overall yield of pulp. The financial analysis of the project is, of course, meaningless under present costs and conditions. However, under the conditions prevailing at that time in 1972, it was indicated that the total investment required would be approximately US\$25 million and that the company could liquidate its debts over a period of from 7 to 9 years.

The first mill scale technical study on kenaf pulping at the Bang Pa-In mill for the UPPC project was reported by Chu, Niyomwan, and Puangvichit (142) of ASRCT and was included as Annex A of the feasibility study (183). Using 17.5 percent active alkali in a modified sulfate cooking process with added sulfur (alkaline polysulfide process), the screened pulp digester yield of 45 percent was obtained from kenaf (H. sabdariffa) whole stalks. The pulp was bleached to 80 percent brightness using added chlorine dioxide in the chlorination stage and peroxide in the alkaline extraction stage of the usual CEHH sequence. Total bleaching chemicals used were 10 percent available chlorine and 1 percent sodium peroxide. The pulp was used to produce a writing paper of good opacity and high smoothness with the kenaf pulp being almost 100 percent of the fibrous furnish with some contamination from straw pulp already in the system.

Further work in 1970 on various grades of kenaf pulp was carried out by one of the advisors for UPPC, Mr. T.P. Ying (143) of Taiwan Pulp & Paper Corp. Mechanical pulp considered for use in newsprint was prepared from kenaf woody core material which had been soaked for 2 hours in boiling water. Chemical pulps were prepared from dried kenaf whole stalks, bast ribbon, and core material. Yields and pulp strength properties reported appear to be typical for each type of pulp as determined by other laboratories.

Another pilot plant pulping trial on whole stalk kenaf was carried out for UPPC by Industrie-Studien- und Entwicklungs-Gesellschaft mbH (ISEGA) (144) at Aschaffenburg, West Germany, in conjunction with Klöckner-Humboldt-Deutz/Pritchard of Koeln, West Germany. After laboratory exploratory cooks and bleaching tests, optimum conditions were established and repeated in a larger scale pulping trial.

Optimum batch pulping conditions chosen for pulping whole stalk kenaf in the ISEGA tests (144) were 15 percent active alkali at 20 percent sulfidity, solids:liquor ratio of 1:4.5, 2 hours to pressure at 160°C and 1 hour on pressure. The resultant digester yield of bleachable grade pulp was 54.3 percent at a Kappa number of 26.3. Using the bleaching sequence CEH, 8 percent total available chlorine was required to reach 81.8 percent GE brightness. Normal strength properties for kenaf whole stalk pulp were maintained in bleaching. In addition, an analysis of spent liquor was made for ash and silica content, viscosity, and heat content.

Voith (141) was also involved in pulping studies on kenaf whole stalk for the UPPC project. The chopped dry kenaf stalks were washed to remove dirt and pith in a laboratory pulper. About 12 to 14 percent of the dry weight of the stalks was lost by this wet cleaning step. Laboratory batch pulping of sulfate pulps gave bleachable pulps of 46 to 49 percent yield across the digester under cooking conditions typical of most kenaf pulping investigations. Bleaching to 82 percent GE brightness was done in 4 stages by the CEHD sequence with added chlorine dioxide in the chlorination stage and hypochlorite in the caustic extraction stage. Similar bleaching results and bleached pulp strength properties were obtained in 3 stages with the CED sequence using chlorine dioxide in the chlorination stage and hypochlorite in the extraction stage.

The Status Report (200) for this project also mentioned Voest of Linz, Austria, had carried out technical and process investigations and Brown & Root in cooperation with Sandy Hill in the U.S.A. had carried out preliminary feasibility and investment studies for UPPC. Information relating to these investigations was not available to the Consultants.

2.6.9.3. Investigations on Kenaf for Paper Pulp by the Applied Scientific Research Corporation of Thailand (ASRCT)

According to Greenhill (145), ASRCT was established in Bangkok in 1964 to conduct research on kenaf as part of its sphere of activities. It has been reported (202) in carrying on a national program of research on kenaf for paper pulp. ASRCT has used the laboratory pulping facilities of the Royal Forestry Department and has made mill trials at the Government-owned Bang Pa-In pulp and paper mill. Financial support for technical personnel for these investigations by ASRCT has also been reported (209) as being furnished by the United Nations Industrial Development Organization (UNIDO).

During the field survey for this Study, the Consultants contacted officials of the ASRCT and were advised that this organization has become a private consulting firm by Government decision. It was also stated that the past reports on the ASRCT work on kenaf for paper pulp have now been classified and that permission would not be granted to review the reports for this Study. This is unfortunate as the work was partially supported by UNIDO and the information could rightfully be considered to be in the public domain because copies of many of the

reports were available in several libraries of the international and governmental agencies in Bangkok. In any event, the Consultants have used abstracts of ASRCT technical reports (146) to locate the earliest of these reports on kenaf for paper pulp and make brief comment as to their subject matter.

In one of the early ASRCT reports, Cavusoglu (147) indicated that kenaf core material appeared to be more suitable than eucalyptus for mechanical pulp for newsprint. It was pointed out that the woody core material normally wasted from the retting process and unsuitable for pulp could be separated by ribboning the whole stalk and used for newsprint. It was suggested that four pulp and paper mills of about 50 tpd. capacity each be established in Northeast Thailand at locations of adequate kenaf supply. It was estimated that in mills of this size, newsprint from kenaf could be produced for less than the cost of imported newsprint.

Cavusoglu and Chu (148) prepared a report determining the maximum price payable for whole stalk kenaf by a 100 tpd. pulp mill located at Khon Kaen in order to produce pulp at a cost competitive to imported pulp. It was estimated that the maximum cost of field dried kenaf stalks delivered to the pulp mill could not exceed \$580 which would yield the farmer the same income as from selling retted fiber at \$2.17/kg.

Chomchalow and Sholton (149) have estimated the savings in cost for imported newsprint and paper pulps by manufacturing kenaf pulps in Thailand.

In one of his earliest reports on kenaf for paper pulp, Chu (150) recommended establishment of kenaf plantations for paper pulp near an existing mill to assess the feasibility of pulp production from kenaf whole stalks and textile wastes.

Laboratory samples of rayon pulp from retted kenaf bast fiber were prepared by Chu and coworkers (151). This product was judged to be a possible market outlet for low grade kenaf bast fiber as a result of this investigation.

The possibilities of kenaf for newsprint have been explored on a technical basis by Chou and coworkers (152). Cold soda pulp was prepared at 55 percent brightness and 75 percent yield from kenaf woody core material. Retted kenaf bast fiber cuttings were cooked with caustic soda and sodium sulfite and a bleachable grade pulp was produced. With 3 stages of bleaching using a total of 10 percent available chlorine, pulp of 85 percent brightness was obtained at an

overall yield from digestion and bleaching of 60 percent. Using pulp furnishes of 80 to 85 percent cold soda pulp from the core material and 20 to 15 percent of the bleached chemical alkaline sulfite pulp from kenaf bast fiber cuttings together with 5 percent kaolin clay, handsheets for testing were prepared. The physical properties of these test sheets using kenaf were comparable to those of newsprint on the market except that the kenaf pulps gave higher tensile and bursting strengths but a lower opacity test than commercial newsprint.

Results of the mill scale run of kenaf whole stalk bleached pulp and the manufacture of writing paper from it at the Bang Pa-In mill in conjunction with the United Pulp and Paper Company, Ltd. project were reported by Chou et al (142) and this work has already been reviewed in Section 2.6.9.2. of this Chapter I.

The laboratory investigations for ASRCT by Chou and coworkers have produced many more technical reports relating to kenaf pulps and the pulping of mixtures of various other fibrous raw materials with kenaf. As these reports (153-169) are not available for review in this Study, they are listed in the bibliography of this Study so that their existence will be recorded. From the titles of these articles it does not appear that these investigations would influence the planning in this Study for a Mekong Basin project mill to use kenaf for the fibrous raw material for full chemical bleached paper pulp.

2.6.9.4. Research on Kenaf Pulping by the Department of Science of the Ministry of Industry (Thailand)

During the field survey in Thailand for this Study, the Consultants contacted the Fiber and Paper Laboratory, Research Division, Department of Science, Ministry of Industry in Bangkok. According to an FAO report (186), this was the first complete pulp and paper laboratory for research established in Thailand. The equipment was supplied by the UNDP and the buildings and services were supplied by the Government of Thailand. With operations starting in 1964, this laboratory began a broad investigation of pulping woods and other fibrous raw materials available in Thailand and the Mekong Basin area.

At the Department of Science, kenaf has been studied extensively for paper pulp and a number of these reports from that laboratory have been made available for this review. It is unfortunate that these excellent studies on kenaf pulps have not been published in the technical journals of the paper industry but were issued as departmental reports that have not found wide circulation in international agencies or other countries where kenaf is being studied.

An investigation was made by Bovorn (170) in which wastes from the kenaf bast fiber baling plants and textile fiber factories were pulped with sulfate cooks. The physical strength properties of the pulps from these kenaf bast fiber wastes had high tensile and bursting strength values but tearing strength was lower than has been found for pulps obtained from the original bast fiber.

This laboratory at that time also prepared an extensive report (171) comparing kenaf (H. sabdariffa) pulps with those from several woods and other nonwood plant fibers. Comparative fiber dimension and chemical analyses were made of the various materials that were pulped. Samples of kenaf whole stalk, bast ribbon and woody core material were pulped and the pulps had yields and physical strength properties typical for the various fractions. It was estimated that at a yield of 40 to 43 percent bleached whole stalk kenaf pulps there could be produced 2.5 tpy/ha. as finished pulp.

Another report (172) covered comparison pulpings of Thai kenaf, jute, and sunn-hemp. Fiber dimensions were measured and chemical analyses were made of the various fractions of these plant stems. The kenaf samples consisted of waste woody core material after retting, the mechanically debarked stem, raw ribbon, whole stalk, and retted bast fiber. Sulfate pulps were prepared from these various forms of kenaf fiber. The bleachable grade unbleached pulp digester yields were 48 percent for the whole stalk, 51 percent for the raw ribbon, 66 percent for the retted bast fiber and 39 to 45 percent for the woody core material. Other pulps of the various fractions of the kenaf stem were prepared by cooking with lime, cold soda pulping, regular full chemical soda pulping, and neutral sulfite and acid sulfite pulping. Some high yield sulfite pulps cooked at various levels of pH on the acid and alkaline sides were also prepared from kenaf stalks. Bleaching trials on sulfate pulps from various kenaf stem fractions were carried out using single stage hypochlorite bleaching, the CEH sequence, and the CEHD sequence. It was determined for whole stalk pulp that use of single stage bleaching required 11.5 percent available chlorine to reach 71 percent Elrepho brightness, the CEH sequence required 7 percent for 76 brightness, and the CEHD sequence required 9.5 percent for 86+ brightness. These studies indicated that excellent papermaking pulps could be produced from kenaf ribbon and whole stalks by the full chemical sulfate pulping process.

It should be noted that one of the UNIDO experts sent to Thailand, Ritman (174), reported that he had recommended to the Department of Science that these particular studies be carried out and that an attempt be made to produce pulp for cultural paper from kenaf whole stalk semi-chemical pulp brightened with 2 percent hydrogen peroxide. However, he judged that this type of brightened pulp at 58 percent brightness from kenaf did not have the required strength properties at neutral sulfite conditions but that an alkaline sulfite pulp would have, based on the test results reported.

Bovorn (173) has reported tests on pulping kenaf whole stalk in comparison with bagasse, rice straw, and Burma grass. It was indicated that while these pulps were suitable for papermaking, some problems remained to be solved.

2.6.9.5. Information Concerning Kenaf Pulping from Miscellaneous Sources in the Mekong Basin Countries

The efforts of Ritman (174) of UNIDO in directing an investigation of high yield sulfite pulping at various pH levels to prepare semichemical pulps for cultural papers has been previously mentioned in connection with the work of the Thailand Department of Science discussed in the preceding section of this chapter. He also studied various aspects of the problems of raw material supply and economics of using kenaf whole stalk for paper pulp in Thailand. It was concluded that kenaf production should be based on an organization of small farmers and that the price for kenaf dry stalks should not be less than US\$35/FDMT and preferably nearer US\$40/FDMT. Ritman also concluded that long fiber pulps could be produced from retted kenaf bast fiber wastes and bast ribbon but that they would be expensive and the supply not dependable. The kenaf whole stalk pulp was considered to be suitable for high quality cultural papers (printing and writing grades) and it was suggested that because of his findings on the unexpectedly high costs of this raw material that the pulp would have to be obtained in high yield and made directly into paper in an integrated pulp/paper mill.

The possibilities for kenaf for paper pulp were discussed by Pairoj (213). He pointed out that the woody core material from the retting of the kenaf stems was too highly stained to be used for mechanical pulp but that core removed by ribboning would be suitable.

In another paper given at the 1973 Workshop on Agro-Industrial Development in the Lower Mekong Basin, Wang (214) discussed the availability of fibrous raw materials for the pulp and paper industry in Thailand. He indicated that the prohibitive factor for the use of kenaf bast fiber would be its high cost in comparison with that for softwoods used for paper pulp. He reported also that kenaf whole stalk pulp would be unsatisfactory for paper pulps and would also have high production costs. This adverse comment was apparently based on the experience with the kenaf pulp trials at the Bang Pa-In mill that were made in conjunction with the UPPC project.

Malenas (215) has given consideration to producing kenaf whole stalk pulp based on a 40 percent unbleached pulp yield and a cost in 1970 of ¥520/FDMT (US\$26.00/FDMT) of baled kenaf delivered to the pulp mill. He recognized the problem of slow drainage of the kenaf whole stalk pulp and considered this form of kenaf to be the most expensive of the major fibrous raw materials (rubberwood, bamboo, mixed tropical hardwoods, Burma grass, pine softwood, bagasse, and kenaf) available for paper pulp in Thailand. It was stated that with the unsolved technical, economic and supply questions relating to kenaf for paper pulp it would be highly questionable that kenaf could be considered at that time as a source of fibrous raw material as long as other and better sources of fiber were available.

Theh (207) and Decha (216) have recently reported that full scale pulping and papermaking mill test runs on Thai whole stalk kenaf for Phoenix Pulp and Paper Company Ltd. were successfully carried out at the Ballarpur Paper & Straw Board Mills, Ltd. in India.

3. The Physical Strength Properties of Kenaf Pulps Compared to Other Major Papermaking Fiber Pulps of the World

3.1. Introduction

An extensive review and discussion of the technical studies carried out on the pulping of kenaf in many laboratories around the world in the last 25 years have been given in the various divisions of Section 2.6 of this Chapter I. It is obvious, from the published data studied, that the most comprehensive work applicable to commercial production has been done mainly on a laboratory scale.

This factor is emphasized because, in the few full-scale mill trials, there does not appear to be a single instance where the pulp has been processed under optimum conditions for producing the highest quality of pulps that can be made out of kenaf in a modern mill employing a fiber wet cleaning system, a continuous digester of the horizontal tube type, and a continuous bleaching system with minimum process capabilities of the CEHD or CEDED bleaching sequences. It would not be difficult to predict from laboratory data the optimum pulping results that could be achieved in such a system when pulping kenaf bast ribbon as that is mostly an homogenous fibrous material. In the case of the kenaf whole stalk pulp, the situation is entirely different and future emphasis needs to be placed on continuous processing in pulping and bleaching to achieve the optimum pulp properties. The fact that the kenaf stalk is not an homogenous fiber material but consists of two zones of different fibers, the bast or nonwood plant type fiber and the core or woody type material, complicates the pulping process. Each of these has greatly differing pulping characteristics under identical conditions, making it necessary to try to reach a balance in pulping whereby, in the mixture of the two as whole stalk, the core material is not too undercooked and the bast material is not too overcooked.

Unfortunately the few actual practical papermaking trial runs resembling commercial operation also have been made in most cases under considerable operating difficulties and equipment limitations. All have been of short duration, allowing insufficient time to bring into necessary balance the pulping, bleaching, and papermaking conditions to achieve the optimum paper product properties obtainable from kenaf pulp.

In addition, the actual papermaking characteristics of the kenaf chemical pulps that could be produced on a commercial basis have not been clearly shown because, in most of the test papermaking runs, pulps from other fibers have been mixed with the kenaf pulp for the papermaking fibrous furnish. Its use in these mixed furnish runs has proved that bleached kenaf whole stalk pulp can be used for making commercially acceptable grades of printing and writing papers. However, the questions have not been answered as to the finished paper physical test and quality properties that could be achieved with 100 percent kenaf pulps of either type in comparison to those of the major grades of paper and paperboard.

Therefore, in analyzing the technical properties of kenaf paper pulps for replacement of the other major grades of pulp in the most important grades of paper manufactured in the Mekong Basin countries¹ mills, it has been necessary to rely upon the available laboratory test data from the more significant studies reviewed earlier in this Chapter I. It must be emphasized again, in comparing data from different laboratories, that there are some differences in equipment, processes, techniques, and reporting and interpreting results between the different laboratories. In addition, it can be expected that there will be variations in results and pulp qualities due to important differences in raw fiber preparation and cleaning and pulping conditions, many of them not clearly defined as being far away from optimum conditions that would be reached in a commercial operation of proper design.

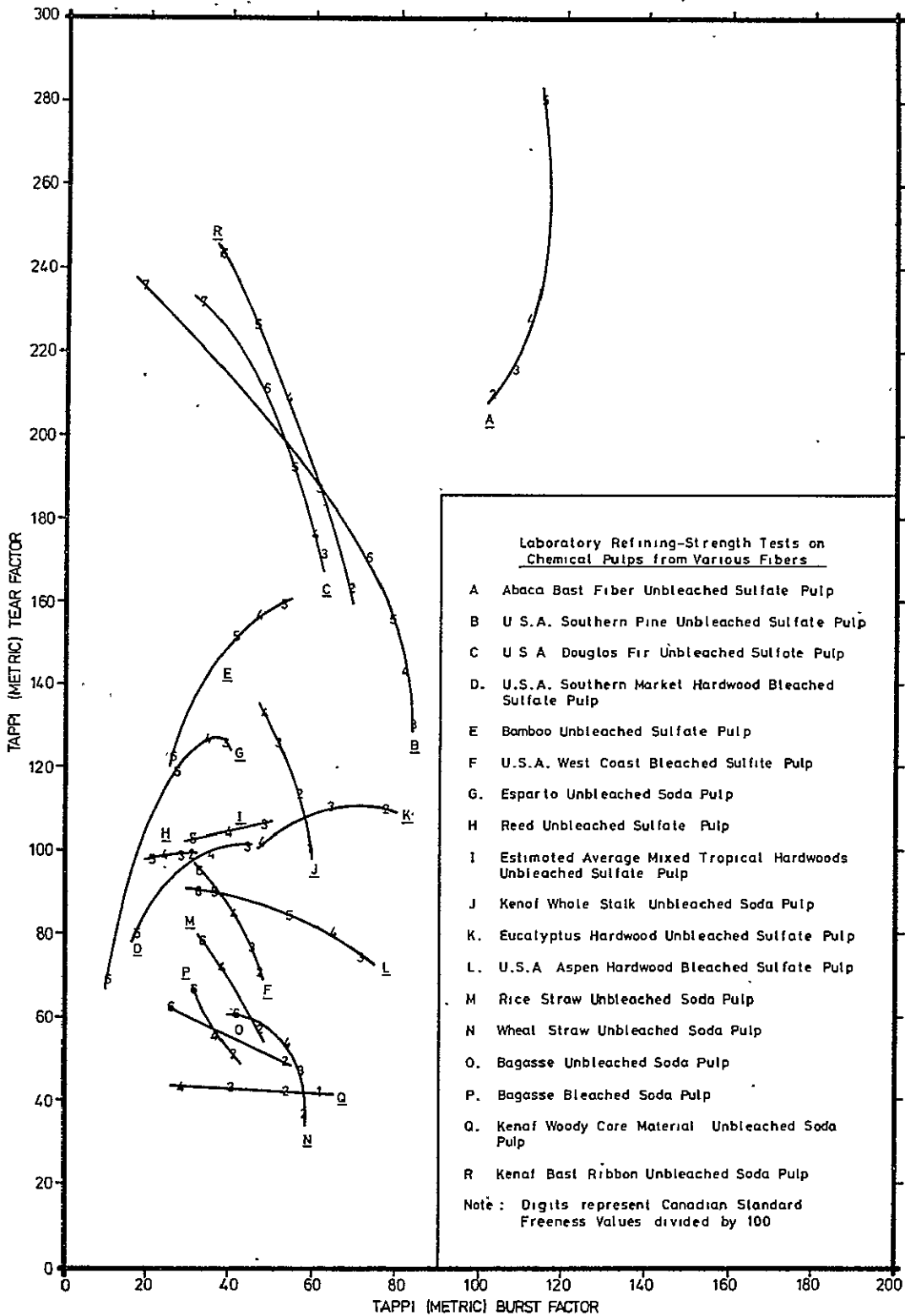
By taking these reservations into consideration, it is believed that a reasonable general comparison can be shown between the laboratory physical strength test data for the three types of kenaf paper pulps and those for the other major pulps used in the world. This will also allow an indication of the grades of paper and paperboard in which the two types of kenaf pulps from the Mekong Basin project mill are expected to find commercial application.

3.2. Comparison of Laboratory Pulp Strength Test Data for Kenaf Paper Pulps with Other Nonwood Plant Fiber and Wood Chemical Pulps

Even with the foregoing admitted possible discrepancies in the test data from the different laboratories, for comparison purposes it has been found useful to consider the so-called standard laboratory beater test data for pulps as having a practical as well as a technical relationship to their papermaking properties. For purposes of effective visual comparison of the various pulps, the laboratory beater (or lab refiner) test data based on metric units used by the Technical Association of the Pulp and Paper Industry (TAPPI) are plotted as shown in Fig. I.1. These values for tear factor and burst factor (or breaking length which gives curves with tear factor which are quite similar in form to the ones obtained by burst factor with tear factor) are taken off of the regular laboratory beater curves at even 100 millimeter (ml.) intervals of the Canadian Standard Freeness Test (C.S.F.). The freeness value is divided by 100 to get a single digit in relation to the tear factor and burst factor at that level of refining of the pulp. The resultant refining-strength curve for the pulp is then drawn through the available points. In cases where the laboratories used the Schopper-Riegler (S.-R.) freeness tester, the freeness data obtained with that equipment were converted to C.S.F. for comparison purposes in this report. It should be pointed out that reporting the refining data in the form of these curves does not give an indication of the comparative amount of beating or refining energy required for a given freeness reduction for the different pulps. This is the case for the standard beater reports where the test values are reported with respect to time, which is proportional to the mechanical energy of refining. Therefore, it is merely pointed out that pulps such as bagasse, straw, and kenaf refine very rapidly and with much less power in comparison with the wood chemical pulps.

Similar curves of laboratory beater test data have been used in past publications by the Consultants (196) and have been found very useful to indicate, from tests on handsheets, the relative papermaking strengths (as expressed by the tear factor and the burst factor in relation to each other at specific freeness levels) of the various pulps. Such visual comparison of these curves for pulps is far more meaningful than the use of the so-called "Strength Index" based on the calculation of a mathematical relationship of several test procedure values. Unfortunately, this system of reporting only the "Strength Index" values, rather than complete standard beater curve data, has been used by the U.S. Dept. of Agriculture researchers

Fig. I.1.



for practically all of their reports on kenaf pulping. Therefore, much of the impact of and comparability for differences in results for their work is not apparent to the reviewer as it would have been from beater curves. Expressing laboratory pulp strength test data as done in this Study would have been very informative for the voluminous USDA data to compare the effects of fiber preparation and cleaning, cooking under varying conditions and by different processes, the various bleaching sequences and conditions, and different refiners, etc. on the resultant kenaf pulp strength data.

In reviewing the reports of the laboratories on pulping trials, it has been found necessary to plot laboratory pulp refining-strength curves from all the available data on kenaf that could be adapted to this mode of expression. The main purpose of this was to try to get an indication of any possibly adverse effects of some of the variations in the pulping studies on the location of the refining-strength curves for the different types of experimental kenaf pulps relative to the data reported for other pulps that are representative of conventional grades being manufactured.

As a result of studying this extensive data on pulping, it was decided that meaningful comparisons of kenaf pulps with the other pulps could best be made by using the data to make an average refining-strength curve for each of the three types of kenaf pulp (bast ribbon, whole stalk, and core material). These are considered to be representative of pulps that could be expected to be produced under optimum conditions in a commercial operation with continuous processing systems considered as suitable for the Mekong Basin project mill.

The three representative refining-strength curves for kenaf pulps are shown in Fig. I.1. in comparison with a wide range of market chemical pulps from hardwoods and softwoods as well as pulps manufactured from tropical hardwoods and other nonwood plant fibers as listed.

The refining-strength curve for the representative optimum kenaf bast ribbon unbleached soda (or sulfate) pulp shows that this type of kenaf pulp is comparable in physical strength properties, as shown in the laboratory beating test, with the representative high strength softwood sulfate (kraft) pulps on the world market. The relatively high initial freeness level for kenaf bast ribbon pulp is a favorable factor in comparison with the softwood sulfate pulps. In addition, it appears that the bast ribbon pulp could be used as a completely interchangeable pulp for the market softwood sulfate pulps in all

grades of papers ranging from paperboards to tissues. This substitution ability would be enhanced particularly where proper procedures for wet cleaning the raw fiber before the pulping operation have been employed. From the data from the various laboratories where experimental bleaching trials have been made, it appears that, with proper pulping conditions followed by optimum bleaching conditions using modern bleaching sequences in commercial operation, the bleached grade of kenaf bast ribbon pulp can be expected to maintain these excellent strength properties. From the standpoint of technical quality, kenaf bast ribbon pulp produced by the Mekong Basin project mill would be considered an equivalent papermaking fiber to that produced from softwoods.

The representative kenaf whole stalk soda (or sulfate) pulp refining-strength curve shows strength properties somewhat higher than for sulfate hardwood and sulfite softwood pulps. This has been achieved by the use of a proper wet cleaning system for the raw fiber before the digester and optimum cooking and bleaching procedures for the mixture of bast and woody core material components of the stalk. The kenaf whole stalk pulp has one serious limitation compared to wood fiber and bast ribbon pulps. That is its very slow drainage rate which will have to be taken into consideration in paper machine wet end design where this pulp is to be used as a high percentage substitution for hardwood sulfate pulp. From some of the technical studies that have been made on kenaf and other nonwood plant fiber pulps, it is quite apparent that fiber fractionation to eliminate part of the fiber fines and cellular or vessel material from the kenaf whole stalk pulp to improve its drainage rate will also improve its papermaking properties as a replacement for hardwood sulfate or softwood sulfite pulps. The improvement in the drainage rate for kenaf whole stalk pulp would, in view of its excellent physical strength properties, also make it far more than an adequate substitute for bagasse or straw pulps for most grades of papers in which they are used.

In fact, the use of this type of kenaf pulp with bagasse or straw pulps in mixed fiber furnishes should allow an appreciable reduction in the percentage of softwood sulfate pulps used and the complete substitution for any hardwood sulfate or softwood sulfite pulps that are used. In addition, it appears that kenaf whole stalk soda pulp can be used as 10 to 15 percent of the furnish for newsprint with the balance of the fiber being mechanical, chemimechanical, thermomechanical or cold soda pulps made from kenaf whole stalk or woody core material.

As for the use of kenaf woody core material for market chemical pulp, the data of the refiner-strength curve show it to be far less satisfactory, from the standpoint of strength properties and the drainage rate, than kenaf whole stalk soda pulp. It would be far more desirable, at least from the technical standpoint if not from the cost standpoint, to use any available woody core material for fuel, semichemical pulp for corrugating medium, mechanical pulp for newsprint, particleboard or fiberboard, or chemical by-products.

Therefore, on the basis of the review of the data from all these laboratory studies, as represented by the refining-strength curves shown, it appears there are no serious technical constraints, from the standpoint of pulp qualities, that would prevent the building of a mill to manufacture kenaf bast ribbon and whole stalk soda or sulfate pulps in the Lower Mekong Basin.

4. The Value of Kenaf as a Raw Material for Paper Pulp Compared to Sugar Cane Bagasse and Wood on a Worldwide Basis

4.1. Introduction

Although comparison values and costs of fibrous raw materials in various countries of the world are important for this Study, they tell only a part of the story and can be very misleading in the overall picture of the final cost of producing pulp and delivering it to market or converting it to paper in integrated mills.

First, there is the matter of final yield of pulp based on the original raw fiber as purchased and delivered to the mill on an equivalent oven dry basis. The parameters of yields for wood and nonwood plant fibers are well known and these calculations are straightforward. This actually only partially determines the value or true cost of one fibrous raw material, based on a ton of finished product, as compared to another raw fiber because such calculations do not consider comparative processing costs among the various materials throughout the entire mill.

Second, there is the matter of the difference in fuel consumption between a pulp mill based on nonwood plant fibers such as bagasse and kenaf, as compared to wood. For example, a modern, efficient, completely self-contained wood pulp mill, including generation of all bleaching chemicals, lime reburning, etc., is estimated to consume about 0.42 MT of oil/ADMT of bleached pulp. A comparable nonwood plant fiber pulp mill, using bagasse or whole stalk kenaf, would use about 0.66 MT of oil/ADMT of bleached pulp. This is in addition to the fuel values recovered as electricity and steam from burning spent pulping liquors and also bark, in the case of the wood pulp mills. This difference in oil usage is due to higher fuel value and content of the organic solids in the black liquor from pulping wood as compared to pulping nonwood plant fibers and the higher requirements of the mills using the latter for steam and power for the evaporators due to the lower spent liquor solids concentration resulting in the pulping and pulp washing operations.

Third, there is also a difference in the capital and resultant interest costs between wood pulp mills and nonwood plant fiber pulp mills of an equivalent productive capacity. This important difference in cost does not show up when only the actual fibrous raw material costs are considered. The more expensive fiber preparation and pulping system, the larger units required in pulp washing and bleaching, the larger evaporators, and the larger causticizing system used in nonwood plant fiber pulp mills, all require a greater investment than for similar process equipment in wood pulp mills of equivalent size. The operating and capital costs of effluent treating systems for nonwood plant fiber pulp mills are also greater than for wood pulp plants and will continue to be so until completely closed recovery systems for the mills are adopted.

Fourth, and apart from the foregoing technical considerations which it is necessary to explain before comparing fibrous raw material costs, there are other differences allowable in costs and reasons for producing kenaf paper pulp in a Mekong Basin project mill as compared to producing wood pulp or paper in other countries and shipping these products into the riparian nations. These factors are the utilization of local raw material, the furnishing of employment and the benefits of increased business activity, the savings in foreign exchange for the national benefit, etc. These items may not enter directly into fibrous raw material costs but they are just as important for consideration as the technical parameters that also indirectly influence the overall true picture of fibrous raw material costs.

It must, therefore, be emphasized, in making the following comparisons of fibrous raw material costs among bagasse, kenaf, and wood, that there are these several other important influencing factors that have to be considered. The overall approximate cost of making pulp can be calculated in a prefeasibility study but a more exact determination of all of these costs will have to be made in a detailed feasibility study. The viability of the Mekong project mill may be more significantly influenced by this combination of factors than by the kenaf fibrous raw material cost delivered to the mill.

4.2. The Cost of Kenaf Whole Stalk in Comparison with Bagasse and Hardwoods as Fibrous Raw Materials for Paper Pulp

The various bases on which pulp mills purchase bagasse from the sugar mills have been discussed in detail by Atchison (34,35). In general, the pulp mill pays the sugar mill the cost of other available fuel required for the replacement of the bagasse for generating an equivalent amount of steam plus some premium which represents a small profit to the sugar mill on the transaction.

For this Study, it is assumed that any surplus bagasse made available by the sugar mill above its own fuel requirements, due to the use of efficient boilers and stack gas dryers for bagasse on the boilers, would be charged for at the same rate as the additional, but not surplus, bagasse released by the sugar mill to the pulp mill and that would have to be replaced with fossil fuels such as natural gas, oil, or coal, or lignite.

It is recognized that there are cases, for example in Thailand at the present time, where the sugar mills are said to have surplus bagasse above their needs for fuel. In some cases they have been willing to sell this bagasse to the pulp mills at a much lower price than fuel replacement value in order to prevent having to burn the excess bagasse as trash just to dispose of it. However, this situation will not exist for long in view of rising fuel costs. Agricultural cellulosic wastes and other fibrous raw materials such as bagasse will eventually reach a delivered-into-the-boiler price at least equivalent to their net value as steam produced in comparison to that produced from the lowest cost other available fuel that could be burned in the boiler.

In the situations for Cases 1 and 2 assumed for comparison here, the sugar company would install and operate the moist depithing and handling equipment for bagasse at the sugar mill. There would be an up-charge of ¥80/ODMT (US\$4.00/ODMT), for the depithed bagasse from the sugar mill over its net fuel value as steam produced, that would cover the capital and operating costs of the moist depithing operation. The 30 percent pith removed from the raw bagasse and the replacement fuel for the depithed bagasse sold to the pulp mill would be burned to generate steam and power for the sugar mill. In this case, the assumption is also made that no capital charge is made against the pulp mill for modification of the boilers in an old sugar mill to burn this combination of substitute fuels instead of the whole

bagasse, although this has been done in many situations. However, in this analysis the differences in boiler efficiencies for the various fuels, based on steam produced, and a premium payment for the moist depithed bagasse of ₪20/ODMT (US\$1.00/ODMT), have been taken into consideration. Storage and handling costs, and transportation costs if any, are not included. However, it is assumed that storage and handling costs would be equivalent for field dried kenaf whole stalk in bales as compared to bagasse in baled or bulk form.

Case 1 - The Cost of Bagasse for Paper Pulp when Oil is the Replacement Fuel for Bagasse

Based on a cost for Bunker C fuel oil of ₪1,800/MT (US\$90.00/MT) delivered to the sugar mill and assuming that the pulp mill is located adjacent to the sugar mill:

	Delivered Cost of Moist Depithed Bagasse to Pulp Mill	
	(₪/ODMT)	(US\$/ODMT)
Value of Bagasse if Converted to Steam (Based on Oil)*	600	30.00
Cost of Moist Depithing	80	4.00
Premium to Sugar Mill	<u>20</u>	<u>1.00</u>
Total	700	35.00

*Note: Based on fuel value that 3.0 ODMT of bagasse at 50 percent moisture equals 1 MT of fuel oil in existing sugar mill boilers.

Therefore, as the final overall yield is 1 ADMT of bleached bagasse pulp for 2.22 ODMT equivalent of moist depithed bagasse leaving the sugar mill, the fibrous raw material cost is ₪1,554/ADMT (US\$77.70/ADMT) of bleached bagasse pulp for market if oil is the replacement fuel for the sugar mill.

Case 2 - The Cost of Bagasse for Paper Pulp when Lignite is the Replacement Fuel for Bagasse

Based on a cost for lignite of ₪310/MT (US\$15.50/MT) delivered to the sugar mill:

	Delivered Cost of Moist Depithed Bagasse to Pulp Mill	
	(¥/ODMT)	(US\$/ODMT)
Value of Bagasse if Converted to Steam (Based on Lignite)*	310	15.50
Cost of Moist Depithing	80	4.00
Premium to Sugar Mill	<u>20</u>	<u>1.00</u>
Total	410	20.50

*Note: Based on fuel value of Mae Moh lignite of 3670 kcal./kg. as mined. In this situation, 3 ODMT of bagasse at 50 percent moisture equals 3 MT of lignite or 1 MT of fuel oil for conversion into an equivalent quantity of steam in actual practice. The cost of lignite is based on a ton price total consisting of ¥130 for lignite at the mine, ¥5 for loading, and ¥175 for rail car freight.

On the basis of this cost of ¥410/ODMT (US\$20.50/ODMT) for moist depithed bagasse leaving the sugar mill, the fibrous raw material cost is ¥910/ADMT (US\$45.50/ADMT) of bleached bagasse pulp for market if lignite is the replacement fuel for the sugar mill.

Case 3 - The Cost of Whole Stalk Kenaf for Paper Pulp

In the case of kenaf, there is the expected yield of 35 percent bleached pulp on an OD basis from field dried whole stalks purchased on an equivalent to OD basis. Therefore, 1.0 ADMT of bleached kenaf pulp would require 2.57 ODMT equivalent kenaf whole stalks which, in order to be in proper condition for wet cleaning as is moist depithed bagasse delivered to the pulp mill, would be fiberized at a cost of ¥40/ODMT (US\$2.00/ODMT) of kenaf. When the necessary cost of fiberizing the kenaf is added to the cost of ¥600/MT (US\$30.00/MT) of field dried kenaf whole stalks delivered in bales, the fiberized raw fiber furnish for the pulp mill would cost ¥1,865/ADMT (US\$93.25/ADMT) of bleached pulp.

Cases 1, 2 and 3 can be summarized as show on the following page:

Case	Fibrous Raw Material	Replace- ment Fuel	Estimated Fibrous Raw Material Cost Based on Bleached Pulp Product*	
			(฿/ADMT)	(US\$/ADMT)
1	Bagasse	Oil	1,554	77.70
2	Bagasse	Lignite	910	45.50
3	Whole Stalk Kenaf	-	1,865	93.25

*Note: This cost includes the cost of fiberizing the kenaf to place it in the same physical condition for processing as is the moist depithed bagasse from the sugar mill.

It will be seen from the preceding calculations that the comparable fibrous raw material cost for bleached bagasse pulp on the unit product basis, when oil is the replacement fuel at the sugar mill, is estimated to be 83 percent of the cost for kenaf whole stalk pulp, based on the delivered cost of whole stalk kenaf as developed in the agro-economic section of this Study. When lignite is the replacement fuel, the fibrous raw material cost for bagasse based on the finished product is only 49 percent of the estimated cost for kenaf whole stalk pulp. If the kenaf whole stalk pulp were required to have the same fibrous raw material cost as the bagasse pulp would have, the pulp mill could only pay ฿494/MT (US\$24.70/MT) based on oil cost or ฿275/MT (US\$13.75/MT) based on lignite cost for the field dried material in bales delivered to the pulp mill gate. Therefore, the bagasse pulp mill would obviously have the advantage of lower cost fibrous raw material per unit of product than for the kenaf whole stalk pulp mill, based on these fuel prices that presently are in effect.

A further debit or credit might also have to be applied against the kenaf raw material, depending on whether or not the freight and handling charges on pulp paid by the kenaf pulp mill in the Mekong Basin area would be greater or less than that paid to get the bagasse pulp to the consuming paper mill. However, that is not considered here. Such estimates and calculations as the foregoing assume equal processing and capital costs for mills producing kenaf whole stalk and bagasse pulp. For this point in the Study, they also assume equal acceptance by the paper mills of the two pulps for certain grades of paper where the higher physical strength characteristics of kenaf whole stalk pulp are not required.

It is interesting to note that calculations for Case 1 show that field dried kenaf at this price for oil has an equivalent fuel-converted-into-steam value of ¥750/ODMT (US\$37.50/ODMT) of whole stalk equivalent or ¥656/MT (US\$32.80/MT) of field dried kenaf at 12.5 percent moisture delivered to the boiler. The equivalent value as fuel of bagasse at 50 percent moisture content, as compared to oil at this price of ¥1,800/MT (US\$90.00/MT), is only ¥600/ODMT (US\$30.00/ODMT) of bagasse. This is because of the lower dry substance content of moist depithed bagasse as compared to whole stalk kenaf that is field dried and the resultant boiler efficiency in present practice of about 60 percent on bagasse at 50 percent moisture as compared to 75 percent expected for the field dried kenaf containing only 12.5 percent moisture. As a replacement for fuel oil, the kenaf whole stalk actually has a ¥56/MT (US\$2.80/MT) higher value as fuel into steam than the ¥600/MT (US\$30.00/MT) that the field dried material is expected to cost delivered to the mill, according to the agro-economic sections of this Study. Therefore, kenaf field dried whole stalks at this price would be worth serious consideration as a possible alternate source of fuel for the Mekong project mill if oil were the only fossil fuel available.

Calculations for Case 2 show that, at this price for lignite, kenaf has an equivalent fuel-converted-into-steam value of ¥388/ODMT (US\$19.40/ODMT) of whole stalk equivalent of ¥339/MT (US\$16.95/MT) of field dried stalks. The equivalent fuel value as steam of raw bagasse at ¥310/ODMT (US\$15.50/ODMT) is the same as the delivered cost of lignite per ton. It is obvious from these estimates that, as compared to lignite, kenaf field dried whole stalks would be too costly to consider as a potential fuel supply. In the case where lignite is substituted at about 52 percent of the present cost of oil for replacement fuel at the sugar mill for the bagasse, the result is a very low cost fibrous papermaking raw material from this source.

With regard to the cost of hardwoods for fibrous raw materials for a pulp mill, the Consultants have recently found that, for large pulp mills being planned for the South Pacific-Asia area, under today's conditions it is expected that mixed tropical hardwood chips delivered to the mill adjacent to the forest area will cost about US\$55.00/ADMT of bleached pulp. This is 59 percent of the fibrous raw material delivered cost compared with that for whole stalk kenaf in bales (and later fiberized) of about ¥1,865/ADMT (US\$93.25/ADMT) of bleached pulp as developed in the agro-economic sections of this Study. In the case of mixed tropical hardwood chips imported into Japan, the cost in 1975 of chips delivered by ship to the dock in Japan was about US\$120.00/ADMT of bleached hardwood pulp and for eucalyptus chips from Australia the cost was about US\$160.00/ADMT of bleached pulp.

In planning a kenaf paper pulp mill for the Mekong Basin area, it should be kept in mind that, eventually, there will be several large bleached hardwood pulp mills built in the South Pacific-Asia area. They will be in a favorable position to supply pulp at competitive world market prices to paper mills in the Mekong riparian countries. They will start pulping the mixed tropical hardwoods initially but will eventually replace these with eucalypts or other fast growing species as plantations are developed. Kenaf whole stalk paper pulp from a Mekong Basin mill would be competing not only with bagasse pulp which could be produced in Thailand and the other riparian countries, but also with the hardwood pulp possibly produced in large pulp mills of at least 250,000 tpy. capacity. Even if the kenaf fibrous raw material were as low in cost per ton of bleached pulp product as the mixed tropical hardwoods - which it will not be - the pulp produced in the large tropical hardwood pulp mills will have the advantage of lower costs in mills each at least four times the size of that contemplated for the Mekong Basin model mill.

The competitive situation from tropical hardwood pulps may not eliminate the possible economic viability for the smaller kenaf paper pulp mill in the Mekong Basin. However, it may be required that an import duty on pulp be imposed by Thailand at a reasonable level to protect the local pulp mill, as justified by the national and regional interests. This point will be discussed again in the financial analysis of the project.

In the case of competitive hardwood market pulps from North America and Scandinavia, the cost situation for kenaf raw materials will not be so disadvantageous, particularly when the pulp transportation cost to the Mekong Basin countries' paper mills is considered. In the southern United States delivered pulpwood costs, based on chip prices, are currently about US\$100.00/ADMT of bleached hardwood sulfate pulp. In Sweden, the cost for pulpwood has recently been reported as high as US\$110.00/ADMT and in Finland US\$130.00/ADMT of bleached hardwood pulp product. When these factors of cost for freight and fibrous raw materials, together with the comparatively high labor costs in these developed countries, are considered, the advantage of "economy of size" for the larger pulp mills in those countries will be somewhat reduced, in comparison to the size of the project mill of this Study, for supplying pulp to the Mekong Basin area paper mills.

4.3. Comparative Costs of Kenaf Bast Ribbon and Softwoods as Fibrous Raw Materials for Paper Pulp

Because the physical strength characteristics are comparable for kenaf bast ribbon soda or sulfate pulps and softwood full chemical sulfate (kraft) pulps, they can be considered for most cases as suitable interchangeable pulp grades for papermaking. Bast ribbon pulp should not be compared on a cost basis with the pulps with lower overall strength properties, such as bagasse, kenaf whole stalk, or hardwood pulps because they are not exactly interchangeable, from the technical standpoint. Kenaf bast ribbon pulp would be used where the usually less expensive, short fiber pulps can not provide the high physical test values required for the final paper product. Therefore, the kenaf bast ribbon pulp and softwood pulps must be considered as competitors for the same market for strong papermaking fibers.

The market softwood sulfate pulps are usually produced in large mills several times the size of the Mekong project model mill. Therefore, they have the cost advantage of "economy of size". However, most of these bleached softwood market pulp mills are located in North America and Scandinavia so that pulp sales, handling, and transportation costs to the Mekong Basin paper mills from these areas are much higher than for pulp produced for internal consumption from kenaf bast ribbon would be.

It is important, when considering the use of the higher cost kenaf bast ribbon for pulping, that the fibrous raw material cost for the competitive softwood sulfate pulps be known.

For example, some of the pulp mills in the interior of British Columbia, Canada, in 1975 were paying US\$60.00/ADMT of bleached pulp for sawmill softwood chips and up to US\$90.00/ADMT of product for pulpwood, delivered to the mill. In Japan, the imported softwood chips from the West Coast of the United States cost delivered in 1975 about US\$180.00/ADMT of bleached pulp. Softwood pulpwood selling in the southern United States, delivered to the mill; for US\$88.00/ADMT of equivalent bleached pulp, in the fall of 1975 was being delivered as chips to mills in Sweden for US\$190.00/ADMT of pulp. Of this, about US\$48.00/ADMT of bleached pulp equivalent was for transportation. This cost is somewhat higher, but acceptable, due to a shortage of pulpwood in Scandinavia, than the US\$145.00/ADMT paid in Sweden or the US\$170.00/ADMT paid in Finland, on a bleached pulp product basis, for softwoods in the same time period.

From the standpoint of raw material cost, it is assumed at this point that the transportation costs and import duties for these pulps from the Western Hemisphere to the Mekong Basin countries' paper mills and high labor costs for those pulp producing countries would tend to reduce the cost advantages resulting from the "economy of size" of their larger mills when compared, on a financial basis, to the project mill of this Study. If this assumption were correct, then on a competitive basis it does not appear at this preliminary point in this Study that the kenaf ribbon pulp mill could afford to pay much more than about P3,000/ADMT (US\$150.00/ADMT) of bleached pulp equivalent for fibrous raw material in the form of field dried kenaf ribbon delivered to the mill. On a basis of a 45 percent bleached pulp yield from the kenaf ribbon purchased, on an equivalent OD basis, this would establish the theoretical delivered price of the kenaf ribbon not to exceed P1,500/ODMT (US\$75.00/ODMT). This would be equivalent to paying P1,313/MT (US\$65.65/MT) of field dried kenaf ribbon delivered, at 12.5 percent moisture content.

Obviously, from the price, as developed in the agro-economic sections of this Study, of P2,080/MT (US\$104.00/MT) for field dried kenaf bast ribbon at 12.5 percent moisture delivered to the pulp mill, this lower payment to the farmer would not be sufficient to persuade him to harvest the kenaf and separate the ribbon unless he could also realize a substantial payment for or benefit from his own use of the woody core material for its fuel value.

The Consultants see possible alternatives to this situation that would deserve serious consideration in a final feasibility study for this project. These would be to develop a system in which the field dried kenaf whole stalks would be broken down by crushing or fiberizing, as is done with sugar cane. Then if most of the bast fiber could be separated from the woody core material at the mill either in a dry process or after moistening, the core material could be used for making mechanical pulp for newsprint or for fuel for generating power and steam.

The analysis of the following two cases assumes that baled, field dried whole stalk kenaf would be delivered to the pulp mill on a year around basis from storage at a moisture content of 12.5 percent and at a cost of P600/MT (US\$30/MT) as is.

Case 1. In this situation, a dry fiberizing and separation process for the bast portion from the woody core material of the field dried kenaf stalks would be required. It must also not decrease the physical strength properties of the resultant pulp because of any adverse effects of mechanical action on the raw fiber. Because of the data given by various investigators that the dry solids weight ratio of bast ribbon : core material varies from 30:70 to 40:60, it is assumed that the dry separation process would recover 30 percent of the dry solids in the stalk as a suitable fibrous pulping substitute for bast ribbon stripped mechanically or by hand from the green stalk. It is also assumed that the dry fiberizing and separation process, including labor, overhead, power, maintenance, supplies, and interest, will cost ₪100/MT (US\$5.00/MT) of baled kenaf and that this cost would all be chargeable to the bast component that would be separated from the core material. Therefore, the field dried kenaf, after processing for separation, would cost ₪700/MT (US\$35.00/MT) with the following components:

0.1250 MT moisture
0.2625 ODMT bast component
0.6125 ODMT woody core component.

Using the calculation procedures of the preceding Section 4.2. of this Chapter I, the monetary value as fuel-into-steam to the mill of this amount of core material component in a ton of field dried kenaf stalk is ₪459 (US\$22.95), based on an oil cost of ₪1,800/MT (US\$90.00/MT) delivered to the mill. The bast component of a ton of field dried kenaf stalks would then cost ₪241 (US\$12.05) or ₪917/ODMT (US\$45.85/ODMT) or ₪802/MT (US\$40.10/MT) of field dried ribbon equivalent based on oil.

At a 45 percent overall yield, this calculated fibrous raw material cost is ₪1,833/ADMT (US\$91.65/ADMT) of kenaf bast ribbon bleached pulp. This is only 61 percent of the ₪3,000/ADMT (US\$150.00/ADMT) of bleached pulp fibrous raw material cost equivalent to the theoretical maximum delivered price of ₪1,313/MT (US\$65.65/MT) of field dried kenaf ribbon that it was previously estimated could be paid in comparison with prices paid for softwood chips in the major market pulp producing countries. This is also 39 percent of the fibrous raw material cost of ₪4,754/ADMT (US\$237.70/ADMT) of paper pulp from kenaf bast ribbon as estimated for actual production in Thailand in the agro-economic sections of this Study.

In the situation where lignite is the fuel available to the pulp mill at a delivered cost of ₪310/MT (US\$15.50/MT), the monetary value of the core material component of a ton of field dried kenaf stalk converted to steam would be ₪237 (US\$11.85). The bast component of a ton of field dried kenaf stalks would then cost ₪463 (US\$23.15) or ₪1,762/ODMT (US\$88.10/ODMT) or ₪1,542/MT (US\$77.10/MT) of field dried ribbon equivalent based on lignite cost.

At a 45 percent overall yield, this calculated fibrous raw material cost is ₪3,084/ADMT (US\$154.20/ADMT) of kenaf bast ribbon bleached pulp. This is only 3 percent more than the ₪3,000/ADMT (US\$150.00/ADMT) of bleached pulp that it was estimated would be the maximum allowable kenaf ribbon fibrous raw material cost competitive with the cost for softwood chips in the major pulp producing countries. However, it is 35 percent below the ₪4,754/ADMT (US\$237.70/ADMT) of paper pulp from kenaf bast ribbon, as estimated for actual production in Thailand in the agro-economic sections of this Study. It is obvious from this calculation that even the low price for lignite does not eliminate the advantage of using the core material for fuel to appreciably lower the cost of the kenaf bast ribbon that might be separated from it in a dry process at the pulp mill.

On the basis of these calculations, it is obvious that the successful development of a dry separation process at the mill for the bast component from field dried stalks would be of great economic value to the project only if oil were the only fossil fuel available. There could be as much of a decrease as 61 percent of the fibrous raw material cost, when based on oil value, that will have to be used later for kenaf bast ribbon pulp in the production financial analysis section of this Study. Where lignite would be available, the reduction in ribbon cost would be 35 percent, if the core material could be separated dry and used for fuel.

Also, by using this dry separation process, for every ADMT of kenaf bast ribbon bleached pulp produced the mill would have for use as fuel 4.67 ODMT or 5.33 FDMT (at 12.5 percent moisture) of woody core material. For generating steam and electricity, this is equivalent to 1.95 MT of oil/ADMT or 5.85 MT of lignite/ADMT of bast ribbon pulp produced. This is 295 percent of the total requirement of the kenaf pulp mill for 0.66 MT of oil/ADMT or 1.98 MT of lignite/ADMT of bleached pulp product.

Based on the balance of production between whole stalk and ribbon pulp, much of the mill's needs for fuel could be met and any excess core material could be burned to generate power for the national grid.

As an alternative to its use for fuel, all or part of the woody core material could be considered for use to produce mechanical pulp for newsprint at the same mill. It is reasonable to assume a 70 percent yield on the OD basis for the mechanical pulp from core material after removal of the fines and water soluble solids in refining, washing, and bleaching and fiber cleaning processes. On this basis, and as an extreme case, the exclusive manufacture of 200 ADMT/day of bleached bast component pulp separated from the woody core material at the mill could make available a supply of 653 ODMT/day equivalent of mechanical pulp for newsprint. On this basis of yield, the fibrous raw material cost, based on its fuel value as oil, of the core material would be $\text{¥}1,072/\text{ODMT}$ (US\$53.60/ODMT) of mechanical pulp. Based on the lignite fuel value, the core material would cost only $\text{¥}554/\text{ODMT}$ (US\$27.70/ODMT) of mechanical pulp. This low cost for the fibrous raw material for mechanical pulp would be a great advantage for the manufacture of newsprint or, conversely, if sold at a higher price to the newsprint mill, could result in lowering the cost of the raw material for the kenaf bast ribbon pulp.

If this amount of mechanical pulp were used as 85 percent of the fibrous furnish with 128 ADMT/day of semi-bleached kenaf bast component pulp in slush form, there could be a newsprint production at this mill of 810 tpd. or 283,500 tpy. This outlet for 64 percent of the chemical pulp production of the Mekong project mill, as planned, would leave only 72 ADMT/day of kenaf ribbon pulp to be marketed or converted to printing and writing papers at the mill.

Obviously, this comment on such an extreme case of this magnitude can not be considered as a recommendation for further study at this time. Eventually, when the final feasibility study for the Mekong project mill is made it should include a newsprint project of size sufficient for the needs of the Mekong Basin countries.

The main purpose of these calculations was to show the quantity and value for fuel of the woody core material that might possibly be separated in a dry process at the mill, if such could eventually be developed, and the effect its utilization would have on the fibrous raw material cost for the kenaf bast component pulp. This information also gives an indication of the economic possibilities for replacing much of the fossil fuel normally required by a pulp mill with core

material that could be provided as a by-product of kenaf bast ribbon production in Thailand for textile purposes. Eventually, if it can be recovered at a low enough cost, the core material could serve as the raw material for the production of mechanical pulp for newsprint, particle-board or fibreboard, or for charcoal or furfural, according to the needs of the local markets.

Case 2. In this hypothetical situation, there would be required a wet fiberizing and separation process for the kenaf whole stalk. It would be equivalent in action to the wet cleaning process used on bagasse and straw and which would be considered for use in cleaning kenaf raw fiber for pulping in regular pulp mill operations. It is assumed that the wet cleaning removes equally from the two fiber components of the stem about 20 percent of the dry solids content consisting of fibrous fines and water soluble materials. Theoretically, this leaching would leave remaining a bast:core ratio of 30:70 on the dry weight basis. It is also assumed that this wet fiberizing and separation treatment costs ¥40/MT (US\$2.00/MT) more than for the dry process or a total ¥140/MT (US\$7.00/MT) of field dried kenaf stalks. Therefore, kenaf after processing and component separation, would cost ¥740/MT (US\$37.00/MT) of field dried stalks equivalent with the following original components:

- 0.1250 MT moisture
- 0.0525 ODMT solids washed out of bast component
- 0.1225 ODMT solids washed out of core component
- 0.2100 ODMT bast component (wet cleaned)
- 0.4900 ODMT core component (wet cleaned).

In the previously discussed dry separation process in Case 1, only the fines and soluble solids that would be removed from the bast component by wet cleaning prior to digestion would go to the effluent treating system or an irrigation water system. In this case, where the wet cleaning is carried out on both components as a step in separating them, the load on the effluent treating system from this department of the mill would be increased by an additional 233 percent. Such an excessive load on the effluent treating system would be economically untenable in proportion to the pulp productive capacity. Hopefully, the problem could be eliminated by using the waste water for irrigation of crops as has been the case for some bagasse pulp mills. In any event, the wet separation process, as compared to the dry separation process, would result in the loss of the fuel value of 0.1225 ODMT of solids from the core component for every ton of field dried kenaf stalks processed. These solids are also assumed to have the same fuel value as other organic components.

of the kenaf. There will also be a significant loss in the value of the woody core material as converted into steam because it can only be pressed to the maximum dry content of 50 percent with conventional equipment at the mill. At this point of moisture content, the new modern boiler efficiency of conversion to steam will be only 65 percent based on the dry solids equivalent Higher Heating Value as compared to 75 percent for the solids separated in the dry process in Case I, where the woody core material contained only 12.5 percent moisture. Also, as a result of the wet cleaning operation, the yield from the washed bast component to finished bleached pulp calculates out to 56.25 percent which would not be unreasonable for this material which would be almost as clean as kenaf bast fiber produced by retting.

Compared to the delivered price of oil at ₦1,800/MT (US\$90.00/MT), kenaf core material at the minimum moisture content of 50 percent achieved by pressing has a fuel value as steam of ₦640/ODMT (US\$32.00/ODMT). Therefore, the fuel value as steam to the system for pressed core material would be ₦314/MT (US\$15.70/MT) of field dried kenaf processed. Calculations from the difference between this value and the estimated cost of a ton of field dried kenaf stalks after wet separation show that the fibrous raw material based on the bast component would cost ₦3,249/ADMT (US\$162.45/ADMT) of bleached pulp based on oil. Although about 8 percent higher than the assumed maximum cost allowable of ₦3,000/ADMT (US\$150.00/ADMT) of bleached pulp for bast component fibrous raw material to be competitive with softwood chip supplies, the cost of the bast component from the wet fiberizing and separation process is only 68 percent (as compared to 65 percent for the dry fiberizing and separation process of Case 1) of the fibrous raw material cost of ₦4,754/ADMT (US\$237.70/ADMT) of bleached pulp based on the delivered cost of ₦2,080/MT (US\$104.00/MT) estimated for field dried kenaf ribbons in the agro-economic sections of this Study.

Compared to the delivered price of lignite of ₦310/MT (US\$15.50/MT), kenaf core material separated by a wet process at a minimum moisture content of 50 percent achieved by pressing has a fuel value as steam of ₦336/ODMT (US\$16.80/ODMT). Therefore, the fuel value of steam to the system for pressed core material in relation to lignite would be ₦165/MT (US\$8.25/MT) of field dried kenaf processed. This results in a fibrous raw material cost for the bast component from the wet separation process of ₦4,384/ADMT (US\$219.20/ADMT) of bleached pulp. This is about 8 percent lower than the cost for pulp for the kenaf ribbons bought directly from the farmers.

Under these conditions, the residual core material at 50 percent moisture and equal to 3.73 ODMT/ADMT of kenaf bast component pulp would produce steam in value equivalent to that produced by 1.33 MT of oil or 3.99 MT of lignite. This is 201 percent of the fuel, in addition to the spent pulping liquor solids, required for the operation of the mill.

In this analysis for Case 2 it is indicated that, where oil is replaced with core material, there is a very favorable possibility for producing a lower cost bast component for pulping even by a technically successful wet separation process. Even where lignite is replaced with the 50 percent moisture core material for fuel, there is still an advantage in lowering the cost of the ribbon fiber to the pulp mill. In the case of the wet separation process, the value of the washed core material for mechanical pulp would remain the same, in relation to the fuel values for oil and lignite, as for the dry separation process, as the soluble dry solids would be removed in the processing into pulp in either case.

There is one other possible situation that can be considered when the pulp mill buys kenaf for pulping delivered to the mill at ₦2,080/MT (US\$104.00/MT) as field dried ribbon. This would have to be based on the assumption that the farmer would also be willing to field dry woody core material after stripping off the bast ribbon. It would then have to be collected and baled and delivered to the mill at a significantly lower price than the delivered cost of baled, field dried kenaf stalks.

Case 3. In this situation, it is assumed that the waste material is delivered to the pulp mill to be used for fuel at a cost of ₦400/MT (US\$20.00/MT) of field dried core material. The supply of this would be assured by the purchase agreement to buy the amount of ribbon, corresponding to this core material, at the price estimated in the agro-economic section of this Study. This would be 67 percent the cost of a ton of field dried kenaf stalks. This price, while merely an assumption, does not appear unreasonable when it is considered that the cost of growing, harvesting, and stripping away the fiber for paper pulp has already been borne by the bast ribbon and that baled, field dried kenaf stalks have been estimated as costing ₦600/MT (US\$30.00/MT) delivered to the mill.

Based on the fuel value as steam compared to oil of ₦750/MT (US\$37.50/MT), or ₦3,390/MT (US\$16.95/MT) compared to lignite, of field dried core material at 12.5 percent moisture content, it is calculated that the resultant cost of the kenaf ribbon fibrous raw material would be ₦3,386/ADMT (US\$169.30/ADMT) of bleached pulp

when the core material replaces oil and ₦5,077/ADMT (US\$253.85/ADMT) when it replaces lignite. The former value is 71 percent of the estimated delivered cost of the hand-stripped bast ribbon for a ton of pulp when there has been no consideration given to the utilization of the woody core material for fuel to replace oil at the mill. However, when lignite is replaced and this price paid for the woody core material delivered, the cost of the kenaf ribbons becomes 7 percent higher than if the core material is not used. The use of the core material as fuel in comparison with lignite would be a break-even proposition if the cost were ₦340/MT (US\$17.00/MT) of field dried core material delivered to the mill.

On this basis, when oil is replaced with core material, the fibrous raw material used for making the long fibered kenaf bast ribbon pulp would become closer to being competitive in cost with raw material for the softwood bleached market pulp than the fibrous raw material cost for whole stalk kenaf pulp in comparison with the mixed tropical hardwood bleached sulfate pulps that are expected to be on the world pulp market in large quantities in future years. This would not be the case, however, at the present cost for lignite.

The figures that have been calculated for Case 3 emphasize another possibility for reducing the high cost of the kenaf bast ribbon by utilizing the waste woody core material as the replacement for oil if it is used at the pulp mill. To pass on an amount equal to the fuel value of the core material as additional money into the hands of the farmers and kenaf industry middlemen should be of sufficient benefit to encourage their participation in such a program. In addition, the use for fuel of the woody core material, now wasted, would add that much to the fuel resources of the country where the project mill would be located.

In summary of Cases 1, 2, and 3:

Case	Situation	Fuel Replaced	Estimated Fibrous Raw Material Cost Based on Bleached Pulp Product*	
			(₦/ADMT)	(US\$/ADMT)
1	Dry Separation Process for Field Dried Kenaf Bast Ribbon from Core Material which is Used for Fuel	Oil	1,833	91.65
		Lignite	3,084	154.20

<u>Case</u>	<u>Situation</u>	<u>Fuel Replaced</u>	<u>Estimated Fibrous Raw Material Cost Based on Bleached Pulp Product*</u>	
			<u>(฿/ADMT)</u>	<u>(US\$/ADMT)</u>
2	Wet Separation Process for Field Dried Kenaf Bast Ribbon from Core Material which is Used for Fuel	Oil	3,249	162.45
		Lignite	4,384	219.20
3	Kenaf Bast Ribbon Separated by Farmer and Equivalent Field Dried Core Material Used for Fuel at ฿400/MT* (US\$20.00/MT)	Oil	3,386	169.30
		Lignite	5,077	253.85
-	Kenaf Bast Ribbon Purchased at ฿2,080/MT (US\$104.00/MT)	-	4,754	237.70
-	Estimated Field Dried Bast Ribbon Price Competitive with Softwoods at ฿1,313/MT (US\$65.65/MT)	-	3,000	150.00

*Note: To compete with lignite as fuel on a cost basis, the field dried core material would have to be delivered to the pulp mill for ฿340/MT (US\$17.00/MT).

The Consultants want to emphasize again that these theoretical calculations have been made to show some possibilities for reducing the fibrous raw material cost for kenaf bast ribbon paper pulp. If the assumptions of either Case 1 or 3 could be met in commercial practice so as to utilize the woody core material as a source of fuel, particularly to replace oil, for the pulp mill or mechanical pulp for newsprint, then kenaf bast ribbon pulp would be on a less disadvantageous fibrous raw material cost basis relative to kenaf whole stalk pulp based on the costs as developed in the agro-economic sections of this Study. The long fiber kenaf bast ribbon pulp would also be in an improved position to compete with softwood market pulps that would otherwise be imported by the paper mills of the Mekong riparian countries.

In using the considerable cost difference between oil and lignite in these calculations relating to the cost of the fibrous raw material supplies, the Consultants are aware of the certainty that, eventually, the price of lignite on a freely competitive market will move closer to the price for oil on an equivalent steam basis. The higher price for lignite will improve the possibilities for utilizing the kenaf core material for fuel and will thereby reduce the cost of the bast ribbon material on the basis of pulp product, as shown by these calculations.

At the present price differential with oil, however, lignite would be a very economical fuel for the Mekong project mill. The large quantity of potential reserves in Thailand of over 235 million tons has been given by the Department of Mineral Resources (197) and this supply source would be a very favorable factor for this project. The Consultants consider the economics of using lignite and kenaf core material for fuel, rather than oil, as one of the most important aspects to be investigated in the final feasibility study for any paper pulp enterprises that would be established in the Mekong Basin area of the riparian countries and particularly in Thailand.

It is noted that, in the foregoing, a 30:70 bast ribbon:core material ratio has been assumed, whereas the agro-economic section of this Study indicates a bast ribbon content of only 24 percent in the whole kenaf stalk. As emphasized repeatedly in this Study the difference between the bast ribbon content figures developed by the U.S. Department of Agriculture and those based on the Consultants' experience with small farmer and commercial bast ribbon production in the developing countries must be the subject of further detailed investigations.

5. The Potential Market for Kenaf Paper Pulp from a Mekong Basin Project Mill

5.1. Introduction

In gathering information on the market potential for kenaf paper pulp in the riparian countries, the Consultants found no up-to-date, centralized compilation of essentially meaningful and correct statistical data on pulp and paper production, consumption, and imports for all four nations of the Mekong Basin.

A summary of statistics of pulp and paper for the most recent data from the Food and Agriculture Organization of the United Nations (FAO) (175) showed that this information relative to the Mekong riparian countries included data only through 1973 and that most of the values were estimated for 1971 and later. In comparison to data which the Consultants have found from local sources in Thailand, the FAO data is completely erroneous and misleading for recent years for that country and so can not be used. This situation indicates the need for support for FAO, or some other international regional organization such as the Mekong Committee, in a program of gathering and reporting, on an annual basis, the correct statistics on pulp and paper imports, production and consumption for the riparian countries.

For this section of the Study, the Consultants have had to rely primarily upon documentation available in Bangkok because it was not possible to make a market survey in the other riparian countries. Much of this information was from past studies of the paper industry in Thailand, data from the Royal Thai Government Customs Department's reports on imports, and estimates by knowledgeable Government officials and companies in the pulp and paper business in Bangkok. The Consultants believe that this information gives a realistic picture of the pulp/paper situation with regard to at least Thailand through 1974. As Thailand would be expected to be by far the major pulp consumer in the riparian countries for many years to come, this will allow a reasonable estimate of the possibilities for marketing kenaf paper pulp from a mill that could be built in the Mekong Basin area by 1980.

Therefore, until the situation for future planning for pulp and paper industries in the other riparian countries becomes clear, the Consultants' estimates of future consumption will have to be based primarily on the historic data for Thailand, as discussed in following sections.

5.2. Capabilities of the Existing Pulp and Paper Industry of the Riparian Countries

The records indicate that there is no existing paper manufacturing industry in Laos and all of that country's requirements have been imported. In the case of Cambodia, until sometime in 1971 a 25 tpd. two paper machine mill for producing printing and writing papers using locally produced straw pulp and imported pulp was reported (176) to have been operated at Chhlong. The status of this mill, or of its equipment, is unknown to the Consultants but it has been indicated that this mill is no longer in operation.

The paper industry in South Viet-Nam was fairly well established with the building of the two largest mills beginning around 1959 which gave the nation a productive capacity of about 50,000 tpy. of paper and paperboard. According to a report by the Economic and Social Studies Division of the Mekong Secretariat (177), it was expected that four pulp mills would be in operation about 1974 to supply a total of about 15,000 tpy. of pulp to the larger paper mills with which they were to be integrated. These mills, listed in Table I.1., are all located in the vicinity of Saigon and Bien-Hoa, South Viet-Nam.

The number of operating mills in Thailand was about 32 according to the most recent lists (178,179,180) available to the Consultants. General information concerning these mills is given in Table I.2. Based upon information for possible pulp markets, data have also been added for estimated pulp and paper production in Thailand if the mills were operated at maximum capacities. The fibrous raw material consumption is an estimate based on the ratio of waste paper to pulp that the mills would prefer to use under ideal market conditions.

From the information in Table I.2., it would appear that, at the present time, the existing four Thailand pulp mills could produce, at maximum operating capacities, about 11,600 tpy. of bleached short fiber pulp from bagasse, grass, and rice straw, about 25,000 tpy. of unbleached short fiber pulp from bagasse, and about 3,500 tpy. of bleached long fiber pulp from bamboo. With this total of about 40,100 tpy. of pulp that could be produced locally, approximately 91,000 tpy. of imported pulp, and approximately 199,750 tpy. of waste paper, about 330,850 tpy. of paper and paperboard could be produced by the paper mills in Thailand under optimum operating and market conditions.

Table I.1.

The Pulp and Paper Industry of South Viet-Nam

Paper and Paperboard Mills

Mill	End Product	Annual Capacity (MT)
Cogido	Printing & Writing, Duplicating, Kraft Paper, Paperboard	22,000
Cogivina	Newsprint, Printing and Writing, Duplicating, Kraft Paper	18,000
Cogimeko	Printing & Writing, Paperboard, Tissue	4,500
Nagico	Printing & Writing, Paperboard	4,500
Dai-Viet	Wrapping Paper	120
General Paper Mill	Tissue	900
International Paper Mill	Tissue	600
Sakygico	Tissue	400
	Total	<u>51,020</u>

Pulp Mills

Mill	Type of Pulp	Fibrous Raw Material	Annual Capacity (MT)
Cogido	Chemical Semichemical	Rice Straw Bagasse	8,500
Cogimeko	Chemical Semichemical	Rice Straw Bagasse	500
Nagico	Chemical Semichemical	Rice Straw Bagasse	500
Cogivina	Mechanical	Wood	<u>5,400</u>
		Total	<u>14,900</u>

Source: (177) Pham Minh Duong. Economic and Social Studies Division, Mekong Secretariat. The Pulp and Paper Industry in South Viet-Nam. MKG/WAID/109 (December 7, 1973).

The Pulp and Paper Industry of Thailand

Name of Company	Products	Estimated Situation for Operation of Mills at Full Capacities				
		Registered Annual Capacity (MT)	Maximum Annual Pulp Production (MT)	Required Annual Pulp Imports (MT)	Annual Consumption of Required Waste Paper (MT)	Total Maximum Paper and/or Paperboard Annual Productive Capacity (MT)
1. Bang Pa-In Paper Factory	Writing & Printing Papers	12,000	8,000 Bleached Rice Straw & Grass	3,500	2,500	14,000
2. Kanchanaburi Paper Factory	Writing & Printing Papers	3,000	3,500 Bleached Bamboo	500(a)	-	3,500
3. Bangkok Paper Factory Co. Ltd. (b)	Writing & Printing Papers	18,000	-	15,000	5,000	20,000
4. Siam Paper Co. Ltd.	Writing & Printing Papers	12,000	3,600 Bleached Bagasse	3,000	5,400	12,000
5. Cardbord (Thailand) Co. Ltd.	Paperboard	6,000	-	3,500	14,000	17,500
6. The Siam Kraft Paper Co. Ltd.	Sack, Linerboard, Corrugating Medium, Wrapping Paper	54,000 (131,000)	25,000 Unbleached Bagasse	25,000	50,000	100,000
7. Mei Nam Paper Industry Ltd.	Tissue	2,190	-	-	1,750	1,750

Table I.2. (A)

Name of Company	Products	Estimated Situation for Operation of Mills at Full Capacities				
		Registered Annual Capacity (MT)	Maximum Annual Pulp Production (MT)	Required Annual Pulp Imports (MT)	Annual Consumption of Required Waste Paper (MT)	Total Maximum Paper and/or Paperboard Annual Productive Capacity (MT)
8. Thai Paper Industries Ltd.	Writing & Printing Papers, Paperboard	800 2,400	- -	- -	- 21,000	- 21,000
9. Burapha Industry Co. Ltd.	Paperboard & Wrapping Paper Straw Paper	1,400 540	- -	- -	- 350	- 350
10. Fah Rung Industrial Co. Ltd.	Paperboard	1,000	-	-	350	350
11. South East Asia Paper Making Factory	Paperboard	96	-	-	-	-
12. Asia Factory Ltd.	Paperboard	240	-	-	-	-
13. C.A.M. Factory	Paperboard	170	-	-	-	-
14. Yu Heng Paper Mill Ltd.	Paperboard	600	-	700	2,800	3,500
15. Krung Thai Paper Industry Co. Ltd.	Paperboard	1,800	-	-	2,100	2,100
16. Sri Thai Industry Co. Ltd.	Straw Paper	600	-	-	-	-
17. Chiang Mai Paper Factory	Straw Paper	300	-	-	-	-

Table I.2.(B)

Name of Company	Products	Estimated Situation for Operation of Mills at Full Capacities				
		Registered Annual Capacity (MT)	Maximum Annual Pulp Production (MT)	Required Annual Pulp Imports (MT)	Annual Consumption of Required Waste Paper (MT)	Total Maximum Paper and/or Paperboard Annual Productive Capacity (MT)
18. Mr. Prayat Khlongsiri Paper Factory	Straw Paper	300				
19. Thai-Scott Paper Co. Ltd.	Tissue	4,500	-	4,800	700	5,500
20. Arkaney Paper Factory Co. Ltd.	Paperboard and Ribbed Kraft	900				
21. Kimberly Clark (Thailand) Co. Ltd.	Tissue	5,760	-	4,000	500	4,500
22. Thai Union Paper Mill Co. Ltd. (b)	Paperboard and Wrapping Paper	20,000	-	17,000	7,000	24,000
23. Thanachot (Dhanachoti) Paper Factory	Writing & Printing Paper, Paperboard	4,500 20,500	-	-	14,000	14,000
24. Sakol Phem Co. Ltd.	Sensitized Paper	120				
25. Krung Tong Paper Industry	Tissue & Wrapping Paper	2,800	-	350	2,450	2,800
26. Krung Tong Paper Industry	Tissue	720				
27. Chin Thai Paper Co.	Printing Paper & Paperboard	1,364	-	1,000	2,500	3,500

Table I.2.(C)

Name of Company	Products	Estimated Situation for Operation of Mills at Full Capacities				
		Registered Annual Capacity (MT)	Maximum Annual Pulp Production (MT)	Required Annual Pulp Imports (MT)	Annual Consumption of Required Waste Paper (MT)	Total Maximum Paper and/or Paperboard Annual Productive Capacity (MT)
28. Ban Klang Paper Factory	Paperboard	7,500				
29. Hiang Seng Fiber Container Co. Ltd.	Corrugating Medium, Linerboard, Sackkraft	66,000	-	10,000	49,500	59,500
30. Capital Paper Co. Ltd.	Paperboard	6,000	-	1,400	5,600	7,000
31. Eastern Industrial Co. Ltd.	Writing & Printing, Paperboard, Wrapping Paper	-	-	1,750	12,250	14,000
32. Thai Paper Mill Samsen (Govt.)	Writing & Printing Paper		-	-	350	350

Notes: (a) Kanchanaburi trades 500 ton/year of bamboo pulp to Bang Pa-In for 500 ton/year of imported long fiber pulp.
 (b) Bangkok Paper Factory, Ltd. and Thai Union Paper Mill Co., Ltd. are under same management.

Sources: (178) Phiphit S., Long-Term Projections of Demand and Supply of Pulp and Paper in Thailand. ASRCT Appraisal Report No. 27 (1974)
 (179) Paichayon U., Economic and Social Studies Division, Mekong Secretariat. Position Paper on the Pulp and Paper Industry in Thailand. MKG/WAID/28 (November 4, 1973).
 (180) Private Business Estimates.

Therefore, if the potential productive capacities of the pulp and paper mills in South Viet-Nam are added to those of Thailand, it would appear that a total of 55,000 tpy. of pulp could be produced as part of the fibrous raw material supply for manufacturing 381,000 tpy. of paper under full operating conditions in the mills existing in the riparian countries at the present time.

5.3. Importation, Production and Consumption of Pulp, Paper, and Paperboard by the Mekong Basin Countries

In assembling the background information for the past statistics on pulp and paper importation, production and consumption for the Mekong Basin countries, the Consultants first considered the available FAO documents (175,181) and found them questionable in accuracy for the last few years because of their use of estimated values since 1971.

The limited data by FAO (175) for Laos showed a consumption of paper and paperboard, of approximately 1,000 MT/year, all imported, for the period 1963-1973.

For pulp/paper statistics for Cambodia, some data on imports, consumption and production have been published by Ly Ky Leang (189) for the years 1967-1969. There are also FAO data (175) for this period. In the single mill pulping bamboo and straw, in 1969 production reached 4,500 MT and the country's pulp imports were 1,200 MT., and total consumption was about 7,800 MT. Over the 1967-1969 period, the paper consumption was rising at an annual rate of about 25 percent. The factory at Chhlong was occupied in April 1970 and was reported as being destroyed.

The pulp/paper statistical data for South Viet-Nam for the period 1970-1972 were published by Pham Minh Duong (177) and prior to that by FAO (175). In 1971, production of paper and paperboard was reported to have reached a high of 48,537 MT. based on 51,695 MT. of imported pulp and waste paper. With the imports of paper and paperboard, this gave a total consumption of 87,106 MT. for that year.

Studies for Thailand by Nipon et.al. (182), Associated Consultants Co., Ltd. (183), Phiphit (178), Phaichayon (179), Cavusoglu (184), the ECAFE Survey Mission (185), ECAFE, The Asian Industrial Survey for Regional Co-operation (208), FAO (186) and various other publications (202,187,188) were reviewed by the Consultants. It is believed that for pulp/paper statistical data for Thailand prior to 1971 these documents can be used for reference but they will not be considered further in this Study because the situation has changed drastically since that time with regard to the paper and paperboard supply in Thailand.

In order to obtain a more recent perspective on pulp/paper statistics for the Mekong Basin countries, during the field survey the Consultants contacted various sources in Bangkok to try to locate a

detailed breakdown of recent data by grades of paper and paperboard. Those contacted included FAO, UNIDO, the United States Embassy, the Ministry of Industry, the Ministry of Commerce, and the Department of Customs, pulp sales companies, major paper companies, and other potential sources.

It was finally concluded that, in order to produce meaningful data in detail of grade breakdown, a system of reporting data by the mills to some official central statistics-gathering agency would be required over a period of several years. However, the Consultants also concluded that actually, for purposes of this Study, some general statistics on pulp/paper reported for the Mekong Basin countries by Pulp & Paper International (190) and Vira (191), together with Thailand's annual import statistics (192), will serve for an estimate to be made of the possible market for kenaf pulp for now and a reasonable period ahead. These data are shown in Tables I.3., I.4., I.5., I.6. and I.7.

It is important to compare the magnitude and the growth from 1960 to 1974 in the per capita consumption of paper and paperboard of the Mekong Basin countries with the consumption in other nations in various areas of the world. This is done in Table I.8. using data collected by Pulp & Paper International (194). Obviously, any improvement in the industrial production level or the standard of living, or an increase in population in the Mekong Basin countries will result in a greatly increased demand for paper and paperboard in comparison to the present situation.

Annual Statistics on Paper and Paperboard for Laos, Cambodia and South Viet-Nam

Country	Imports, Production, and Consumption (MT/Year)					
	1969	1970	1971	1972	1973	1974
<u>Laos</u>						
<u>Paper & Paperboard</u>						
Imports	2,500	2,612	2,705	2,830	2,830	2,800e
Production	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Total Consumption	2,500	2,612	2,705	2,830	2,830	2,800e
<u>Cambodia</u>						
<u>Paper & Paperboard</u>						
Imports	7,000e	3,500	2,000e	2,000e	2,500e	2,500e
Production	<u>5,000e</u>	<u>3,900</u>	<u>3,000e</u>	<u>0</u>	<u>0</u>	<u>0</u>
Total Consumption	12,000e	7,400	5,000e	2,000e	2,500e	2,500e
<u>South Viet-Nam</u>						
<u>Pulp</u>						
Imports	10,800e	22,000e	24,000e	24,000e	26,000e	-
Production	<u>11,700e</u>	<u>11,700e</u>	<u>12,000e</u>	<u>12,000e</u>	<u>12,000e</u>	<u>-</u>
Total Consumption	22,500e	33,700e	36,000e	36,000e	38,000e	-
<u>Paper & Paperboard</u>						
Imports	41,400e	42,000e	42,000e	45,000e	47,000e	-
Production	<u>21,600e</u>	<u>42,823e</u>	<u>44,000e</u>	<u>44,000e</u>	<u>45,000e</u>	<u>-</u>
Total Consumption	63,000	84,823	86,000	89,000	92,000	-

Source: (190) Anon. Pulp Paper Intern. (Annual Review Numbers, 1971-1975).

Table I.4.

Annual Statistics on Paper and Paperboard for Thailand

Country	Exports, Imports, Production, and Consumption (MT/Year)					
	1969	1970	1971	1972	1973	1974
<u>Thailand</u>						
<u>Pulp</u>						
Imports	32,020	52,515	44,234	81,688	84,225	78,500e
Production	11,500	20,140	22,385	26,700	36,000	45,000
<u>Wastepaper</u>						
Used	<u>14,100</u>	<u>21,215</u>	<u>46,680</u>	<u>45,300</u>	<u>42,000</u>	<u>48,000e</u>
Total Fiber Consumption	57,620	93,870	113,299	153,688	162,225	171,500e
<u>Paper & Paperboard</u>						
Imports	142,828	100,129	105,517	92,912	105,445	91,000e
Exports	<u>146</u>	<u>1,228</u>	<u>2,168</u>	<u>3,671</u>	<u>7,000</u>	<u>10,000e</u>
Net Imports Above Exports (1)	142,682	98,901	103,349	89,241	98,445	81,000e
Paper Production						
Printing & Writing	-	-	-	-	52,100	43,530
Wrapping Paper	-	-	-	-	38,000	40,000
All Other Papers	-	-	-	-	14,700	18,600
Total Paper (2)	42,560	75,420	75,152	89,967	104,800	102,130
Paperboard Production						
Container Paperboard	?	?	?	?	40,000	35,000
Other Paperboard	-	-	-	-	15,300	25,300
Total Paperboard (3)	<u>9,850</u>	<u>9,920</u>	<u>33,800</u>	<u>57,200</u>	<u>55,300</u>	<u>60,300</u>
Total Paper and Paper- board Produced (2 + 3)	<u>52,410</u>	<u>85,340</u>	<u>108,952</u>	<u>147,167</u>	<u>160,100</u>	<u>162,430</u>
Apparent Total Paper and Paperboard Consumption (1 + 2 + 3)	<u>195,092</u>	<u>184,241</u>	<u>212,301</u>	<u>236,408</u>	<u>258,545</u>	<u>243,430</u>

Source: (191) Vira S., Pulp Paper Intern. (Annual Review Numbers, 1971-1975).

Note: Prior to 1973 container paperboard was not separated and was probably included in the total paper.

Thailand - Imports of Pulp and Waste Paper

Grade	1970		1971		1972		1973		1974	
	(MT)	(£,000)	(MT)	(£,000)	(MT)	(£,000)	(MT)	(£,000)	(MT)	(£,000)
Mechanical Wood Pulp	15,545	23,512	12,196	46,533	18,349	58,499	13,744	70,331	8,789	71,997
Pulp Other Than Wood Pulp	17,570	64,467	13,896	49,981	15,477	27,250	2,663	14,733	5,902	39,676
Dissolving Pulp	796	2,829	2,443	7,775	490	2,355	625	1,837	552	2,719
Sulfate Wood Pulp (Unbl.)	-	-	250	949	18,216	61,861	16,433	57,064	21,845	171,872
Sulfate Wood Pulp (Bl.)	9,611	37,025	7,585	27,707	15,747	56,026	21,115	110,048	12,677	105,178
Sulfite Wood Pulp (Unbl.)	-	-	207	748	1,147	3,957	16,424	67,768	4,765	38,042
Sulfite Wood Pulp (Bl.)	8,970	31,318	6,967	26,636	11,507	33,636	12,572	67,406	14,921	135,832
Semi-Chemical Wood Pulp	1,716	5,428	686	2,627	751	2,502	649	3,071	-	-
Waste Paper for Recycling	11,651	24,533	13,348	31,237	19,152	23,511	23,530	36,129	79,255	241,156
Totals	65,859	189,112	57,578	194,193	100,836	269,599	107,755	428,387	148,706	806,472
(C.i.f. value - US\$,000)		(9,456)		(9,710)		(13,480)		(21,420)		(40,324)

Note: US\$1.00 = £20.

Source: Department of Customs (Thailand). Foreign Trade Statistics of Thailand. (December issue each year).

Thailand - Imports of Major Grades of Paper and Paperboard

Grade	1970		1971		1972		1973		1974	
	(MT)	(฿,000)	(MT)	(฿,000)	(MT)	(฿,000)	(MT)	(฿,000)	(MT)	(฿,000)
Kraft Paper	5,825	21,851	5,586	20,275	3,379	12,570	1,022	6,843	1,651	18,652
Kraft Paperboard	2,820	9,430	1,695	5,765	434	1,512	-	-	179	1,146
Other Paperboard	3,174	12,577	2,674	9,629	972	6,185	373	1,945	77	1,232
Newsprint	36,312	108,819	54,908	178,391	50,305	178,438	55,610	280,176	57,669	467,566
Printing & Writing*	4,526	24,548	4,175	28,767	6,051	30,970	5,763	28,808	3,486	35,648
Other Paper & Paperboard	<u>9,725</u>	<u>56,758</u>	<u>6,599</u>	<u>44,955</u>	<u>3,468</u>	<u>28,730</u>	<u>2,810</u>	<u>27,369</u>	<u>2,417</u>	<u>35,284</u>
Totals	62,382	233,983	75,637	287,782	64,609	258,405	65,578	345,141	65,479	559,528
(C.i.f. value - US\$,000)		(11,700)		(14,389)		(12,920)		(17,257)		(27,976)

Note: US\$1.00 = ฿20. *Uncoated grades.

Source: Department of Customs (Thailand). Foreign Trade Statistics of Thailand. (December issue each year).

Thailand - Imports of Specialty Grades of Paper and Paperboard and Converted Paper Products

Grade	1970		1971		1972		1973		1974	
	(MT)	(฿,000)	(MT)	(฿,000)	(MT)	(฿,000)	(MT)	(฿,000)	(MT)	(฿,000)
Miscellaneous Grades of Specialty Papers and Paperboards*	2,444	27,480	3,336	34,693	8,370	40,597	13,177	71,175	3,506	43,621
Converted Paper and Paperboard Products, Books Printed Materials, etc.	<u>36,500</u>	<u>374,473</u>	<u>28,253</u>	<u>371,165</u>	<u>25,184</u>	<u>340,714</u>	<u>30,064</u>	<u>459,326</u>	<u>20,087</u>	<u>435,072</u>
Totals	38,944	401,953	31,589	405,858	33,554	381,311	43,241	530,501	23,593	478,693
(C.i.f. value - US\$,000)		(20,098)		(20,293)		(19,066)		(26,525)		(23,935)

Note: *Building board products are not included. US\$1.00 = ฿20.

Source: Department of Customs (Thailand). Foreign Trade Statistics of Thailand. (December issue each year).

Table I.8.

Paper and Paperboard Used in Some Countries of
the World: 1960-1974

Area and Country	Consumption of Paper and Paperboard (Kg./Year/Capita)		
	1960	1970	1974
<u>North America</u>			
Canada	127	169	196 (Least)
United States	196	252	279 (Highest)
<u>Europe</u>			
Albania	8	5	5 (Least)
Sweden	120	191	220 (Highest)
W. Germany	79	125	132
France	58	94	115
United Kingdom	107	129	142
U.S.S.R.	15	27	31
<u>Latin America</u>			
Haiti	1.4	0.5	0.6 (Least)
Costa Rica	7	67	63 (Highest)
Argentina	29	41	36
Brazil	10	14	21
Mexico	15	24	26
Ecuador	4	29	7
<u>Africa</u>			
Burundi	-	0.2	0.03 (Least)
South Africa	27	42	50 (Highest)
Algeria	2	8	10
Ghana	3	4	-
Kenya	-	4	6
Nigeria	0.9	0.9	1.8
United Arab Rep.	5	7	5
Zaire	1.4	0.9	0.7
<u>Asia & Oceania</u>			
Afghanistan	0.2	0.1	0.1 (Least)
New Zealand	80	114	146 (Highest)
China - Mainland	1.8	5	9
India	1	2	2
Japan	47	122	140
Indonesia	1.8	1.0	1.7
Cambodia	1.3	0.8	0.3
Laos	1.8	0.9	0.9
Thailand	2.3	7.3	6
South Viet-Nam	2.3	3.6	5

Source: (194) Anon. Pulp Paper Intern. 17, no. 8:18-9 (Rev. Number, July 25, 1975).

5.4. Estimates of Future Markets for Kenaf Paper Pulp in the Mekong Basin Countries

On the basis of available information, it does not appear to the Consultants that Laos or Cambodia can be expected to be markets for kenaf paper pulp for the foreseeable future or that pulp and paper mills will be built in those countries to supply their local requirements only. As discussed in Section 6.3. of this Chapter I, there are potential sites in both countries within the Lower Mekong Basin for a kenaf market paper pulp mill. However, these locations are not as favorable as sites in Thailand. Also, the low level of consumption of paper in those countries would not favor the installation of papermaking machinery of any significant capacity at a kenaf market pulp mill for paper production for the local markets. Therefore, practically all pulp that would be produced would have to be exported to Thailand, the major consumer, and South Viet-Nam. It would be far more economical for Cambodia and Laos to supply kenaf ribbon to the Mekong model pulp mill in Northeast Thailand or South Viet-Nam in exchange for the major grades of paper and paperboard which those countries should be able to produce in the future in relatively large scale production units.

In the case of South Viet-Nam, when the consumption of pulp and paper eventually regains the levels of the period from 1970 through 1973, it appears that the country will then require imports of 45,000 tpy. of paper and paperboard and 25,000 tpy. of pulp or pulp substitutes in the form of waste paper. Without a detailed breakdown of consumption of these imported products by grades, it is difficult to judge how much kenaf paper pulp could be used if it were purchased from the Mekong Basin project pulp mill and the paper and paperboard were purchased from a paper mill in Thailand supplied with kenaf pulp from the Mekong project mill. If the kenaf pulp were available as bleached and unbleached whole stalk and bast ribbon grades, it would be reasonable to estimate that this pulp/paper product consumption in South Viet-Nam would provide a final market outlet equivalent to a total of 15,000 to 20,000 tpy. of kenaf paper pulp before 1980. This possibility for trade between Mekong Basin nations might be enhanced if South Viet-Nam could supply an appreciable amount of the kenaf ribbon fibrous raw material at reasonable cost delivered to the Mekong Basin project mill.

For Thailand, based on the production and consumption data available, the possible markets for kenaf paper pulp would be in replacing a large percentage of the imported hardwood, softwood, and "pulp other than wood pulp" pulps used by the existing paper and

paperboard mills. There are also the necessity and possibility for replacing the 14,000 tpy. of bleached bagasse, grass, and bamboo pulps, presently produced in the three small pulp mills in Thailand, with kenaf paper pulp. This is based on the need at these existing pulp mills for spent pulping liquor recovery systems to save on pulping chemical costs and to reduce by more than 90 percent the stream pollution that results at the present time from these mills due to dumping this spent pulping liquor.

It would appear reasonable to consider that bleached or semi-bleached whole stalk kenaf pulp would replace about 20,000 tpy. of bleached and unbleached sulfite pulps and another 5,000 tpy. of "pulp other than wood pulp", probably bleached bagasse pulp from Taiwan, formerly being imported.

In the case of bleached sulfate wood pulps there are the possibilities of replacement of perhaps 7,500 tpy. of hardwood pulp with bleached kenaf whole stalk pulp and 7,500 tpy. of softwood pulp with bleached kenaf ribbon pulp.

The Consultants assume that the imported unbleached sulfate pulp for Thailand is softwood pulp used in linerboard and industrial papers. It is also realized that part of this will eventually be replaced with the long fibered fraction of pulp that could be fractionated out of recycled pulp made from waste corrugated containers. For that reason, the Consultants estimate that only half, amounting to 10,000 tpy. at present, of the imported unbleached sulfate pulp would be replaced with unbleached kenaf ribbon pulp.

Therefore, in summary, the pulp replacement possibilities with kenaf paper pulp in the Mekong Basin countries appear to be as shown in Table I.9. The Consultants have also estimated a future projection of the kenaf paper pulp that could be used in paper and paperboard for the Mekong Basin countries in 1980, by the earliest possible mill starting time, and by 1985. These estimates are based on a relatively low growth rate in total consumption of paper and paperboard that would use kenaf paper pulp for all the Mekong Basin countries of only 3.5 percent to 1985. This is felt to be a conservative estimate in view of the fact that for Thailand, for the period from 1969 through 1974, the growth rate of apparent consumption of basic grades of paper and paperboard was 4.5 percent on an annually compounded basis and would not now be expected to be this high for the other riparian countries.

Table I.9.

Estimates of Domestic Chemical Pulp Supplies and Pulp and Paper Imports of the
Mekong Basin Countries Replaceable with Kenaf Paper Pulp Products

Present Imports	Replacement with Kenaf Pulp Products	
	Pulp Type	(ADMT/Year)
	<u>Laos</u>	
Paper	Bleached Whole Stalk Pulp	500
Paper	Unbleached Ribbon Pulp	250
Paperboard	Unbleached Ribbon Pulp	250
	Country Total	1,000
	<u>Cambodia</u>	
Paper	Bleached Whole Stalk Pulp	1,000
Paper	Unbleached Ribbon Pulp	500
Paperboard	Unbleached Ribbon Pulp	500
	Country Total	2,000
	<u>South Viet-Nam</u>	
Pulp and Paper	Bleached Whole Stalk Pulp	7,500
Pulp and Paper	Bleached Ribbon Pulp	5,000
Pulp and Paper	Unbleached Ribbon Pulp	5,000
	Country Total	17,500
	<u>Thailand</u>	
Domestic Bagasse & Grass Pulp	Bleached Whole Stalk Pulp	11,000
Domestic Bamboo Pulp	Bleached Ribbon Pulp	3,000
Sulfite Pulps	Bleached Whole Stalk Pulp	20,000
Other than Wood Pulp	Bleached Whole Stalk Pulp	5,000
Bleached Hardwood Sulfate Pulp	Bleached Whole Stalk Pulp	7,500
Bleached Softwood Sulfate Pulp	Bleached Ribbon Pulp	7,500
Unbleached Softwood Sulfate Pulp	Unbleached Ribbon Pulp	10,000
Imported Printing & Writing Papers	Bleached Whole Stalk Pulp	2,000
Imported Converted Paper Products	Bleached Whole Stalk Pulp	2,500
Imported Converted Paper Products	Bleached Ribbon Pulp	2,500
Newsprint	Bleached Ribbon Pulp	5,000
	Country Total	76,000
	<u>Summary</u>	
	Total Equivalents of:	
	Bleached Kenaf Whole Stalk Pulp	57,000
	Bleached Kenaf Ribbon Pulp	23,000
	Unbleached Kenaf Ribbon Pulp	16,500
	Kenaf Pulp for Mekong Basin Total	1975 96,500
	@ 3.5% Paper Consumption Growth Rate	1980 114,600
	@ 3.5% Paper Consumption Growth Rate	1985 136,100

There is also another possible market for semi-bleached kenaf whole stalk or ribbon chemical pulp if a newsprint mill, based mainly on bagasse or kenaf or wood mechanical, thermomechanical, and chemimechanical pulps, is ever established in the countries of the Lower Mekong Basin. Based on the total replacement with the locally produced product of an estimated 60,000 tpy. of newsprint, estimated to have been imported into the Mekong Basin countries in some recent years, the full chemical kenaf pulp requirements might be another 5,000 to 10,000 tpy., depending upon the technical requirements for long fibered kenaf pulp in the newsprint furnish.

Therefore, on the basis of these estimates, the Consultants believe that, under the present situation and if a newsprint mill of adequate capacity is built, a market exists in the Mekong Basin countries for more than the 70,000 tpy. of kenaf paper pulp that the project mill of this study would produce. However, if other integrated bleached pulp/paper mills based on bagasse and/or bamboo of at least similar productive capacity were to be implemented before the mill considered in this Study, the possibility, from the market standpoint, for building a kenaf paper pulp mill of the minimum size of 70,000 tpy. that should be considered would probably not be favorable for another 10 to 15 years. This would be particularly the case where the use of bagasse or bamboo for pulp and paperboard manufacture has cost and supply advantages in comparison with kenaf whole stalk or ribbon and if the possible technical advantages of kenaf paper pulp do not give this grade a strong competitive marketing edge over the paper products made from the pulps from the other fibrous raw materials. This possibility for failure to find markets for the kenaf paper pulp is based on the assumption, at this point, that kenaf paper pulp would not find long range export opportunities on the world market at a reasonable sales profit in competition with hardwood and softwood chemical pulps.

It should be understood that the possibility of this competition for local markets and the needs of the riparian countries for additional productive capacity for some of the major bleached paper grades, such as printing and writing papers, are the main reasons for the recommendations by the Consultants in this Study that the pulp dryer for the project mill must be designed for eventual conversion to the manufacture of paper and paperboard. This pulp dryer must be designed as a fourdrinier-type machine with can-type dryers so that a minimum investment would be required later to add additional equipment enabling the manufacture of paper as well as pulp as the market demand grows.

This eventual conversion to paper manufacture for part or all of the capacity of the Mekong project mill would then allow some of the existing low capacity, higher cost marginal paper mills in Thailand to switch to recycled waste paper product grades or to be shut down. This favorable factor in the planning would be an added advantage for the contemplated kenaf for paper pulp project.

Projections by the Consultants for the overall consumption of paper and paperboard in the Mekong Basin countries, other than for the kenaf paper pulp component of the grades that could possibly be made with it as all or part of the fibrous furnish, are outside the scope of this Study. However, it is interesting to consider the projections and percentage annual growth rates of total paper and paperboard consumption in the riparian countries made in previous studies (177,178,179,185, 186,187,189,208). For comparison purposes, the data from these prior investigations are condensed in Tables I.10., I.11., I.12., and I.13.

These studies have, in general, projected growth rates for total paper and paperboard consumption in the Mekong Basin countries within the range of 7 to 10 percent compounded annually. The Consultants believe these growth rates are too high and are unrealistic when the actual increase in consumption in Thailand for the period 1969-1974 was only about 4.5 percent. It is apparent that these estimates were made at the end of a period of rapid expansion of paper production and consumption in Thailand in the period 1960-1970 when, as various studies have shown, the annual growth rate of consumption was actually between 10.5 and 12.5 percent and production increased by 19 to 30 percent, depending upon differences in statistical data used in the studies. Such high growth rates as these are typical when a developing country with a very low per capita consumption of paper as a base to start with enters a period of prosperity and increased business activity and establishes some large production units where only a few very small mills existed previously, as has been the case in Thailand.

Although the projections were conservative at the time they were made, the Consultants find from the data of recent years that they are no longer valid. In their opinion, the total paper and paperboard consumption growth rate of the Mekong Basin countries will probably not exceed five percent annually for the next ten years unless some very drastic unforeseen change occurs.

There are many other factors which weigh against reaching the high consumption levels that have been projected by others for the Mekong Basin countries. Among these are the present limitation of an overall

Table I.10.

Projections for Paper Consumption for Laos

Grade	Estimated Projections of Consumption 1970-1985				
	(-,000 MT/Year)				Annual Growth Rate (%)
	1970	1975	1980	1985	
Printing & Writing Paper	0.6	0.7	1.2	1.8	7.6
Newsprint	0.3	0.3	0.8	0.9	7.6

Source: (208) ECAFE. Asian Industrial Survey for Regional Co-operation. Proposals for Regional Co-operation in the Field of Pulp and Paper Manufacture. Study No. 2 (August, 1972).

Table I.11.

Projections for Paper Consumption for Cambodia

Grade	Estimated Projections of Consumption 1970-1985				
	(-,000 MT/Year)				Annual Growth Rate (%)
	1970	1975	1980	1985	
Printing & Writing Papers	2.8	4.1	5.8	9.0	8.1
Newsprint	2.1	2.5	3.9	5.6	6.8

Source: (208) ECAFE. Asian Industrial Survey for Regional Co-operation. Proposals for Regional Co-operation in the Field of Pulp and Paper Manufacture. Study No. 2 (August, 1972).

Estimated Total Consumption for Cambodia by 1980 37,000 MT
Minimum Paper Consumption Growth Rate 10 %

Source: (189) Ky Ly Léang, Paper Manufacturing in the Khmer Republic. Economic and Social Studies Division, Mekong Secretariat MKG/WAID/81 (November 28, 1973).

Table I.12.

Projections of Paper Consumption for South Viet-Nam

Grade	Estimated Projections of Consumption 1970-1985				Annual Growth Rate (%)
	(-,000 MT/Year)				
	1970	1975	1980	1985	
Printing & Writing Paper	9.0	11.9	17.4	28.7	8.0
Newsprint	19.8	25.8	37.0	52.5	6.7

Source: (208) ECAFE. Asian Industrial Survey for Regional Co-operation. Proposals for Regional Co-operation in the Field of Pulp and Paper Manufacture. Study No. 2 (August, 1972).

Grade	Estimated Projections of Consumption 1973-1982				Annual Growth Rate (%)
	(-,000 MT/Year)				
	1973	1976	1979	1982	
Total	88.3	112.5	143.2	182.4	8.4

Source: (177) Pham Minh Duong, Economic and Social Studies Division, Mekong Secretariat. The Pulp and Paper Industry in South Viet-Nam. MKG/WAID/109 (December 7, 1973).

Table I.13.(A)

Projections of Paper Consumption for Thailand

Grade	Estimated Projections of Consumption 1967-1977				
	(-,000 MT/Year)				Annual Growth Rate (%)
	1967	1970	1975	1977	
Printing & Writing Paper	36.5	48.0	77.0	94.0	9.9
Newsprint	35.0	45.0	70.0	84.0	9.2
Paperboard	33.0	45.0	73.0	86.0	10.0
Other Papers	21.0	28.0	48.0	59.0	10.9
Total	125.5	166.0	268.0	323.0	9.9 Av.

Source: (185) ECAFE Survey Mission, Report of the Survey Mission on the Pulp, Paper and Rayon Industry in South-East Asia. United Nations, Economic Commission for Asia and the Far East, Asian Industrial Development Council. Document AIDC (3)/2 (Dec. 6, 1967).

Grade	Estimated Projections of Consumption 1970-1985			
	(-,000 MT/Year)			Annual Growth Rate (%)
	1970	1975	1985	
Printing & Writing Papers	46.0	67.5	143.0	7.8
Newsprint	43.5	65.0	141.5	8.2
Industrial Paper	62.0	93.5	209.0	8.4
Total	151.5	226.0	493.5	8.2 Av.
Maximum	163.5	254.8	595.0	9.0 Max.
Minimum	139.0	196.8	391.2	7.1 Min.

Source: (186) FAO. Paper and Pulp Material Survey: Thailand Vols. I and II. Document FAO/SF:46/THA-11 Rome (1968).

Grade	Estimated Projections of Consumption 1970-1985				
	(-,000 MT/Year)				Annual Growth Rate (%)
	1970	1975	1980	1985	
Printing & Writing Paper	35.8	58.5	93.0	152.5	10.1
Newsprint	46.5	71.0	117.5	192.0	9.9

Source: (208) ECAFE. Asian Industrial Survey for Regional Co-operation. Proposals for Regional Co-operation in the Field of Pulp and Paper Manufacture. Study No. 2 (August, 1972).

Table I.13.(B)

Grade	Estimated Projections of Consumption 1970-1985				
	(-,000 MT/Year)				Annual Growth Rate (%)
	1970	1975	1980	1985	
Writing & Printing Paper	39.8	54.8	70.5	91.9	5.8
Newsprint	36.3	62.3	89.1	126.3	8.7
Industrial Paper	89.9	131.6	204.1	306.9	8.5
Tissue Paper	5.9	12.8	19.9	29.2	11.2
Total	171.9	261.5	383.6	554.3	8.1 Av.

Source: (179) Paichayon U., Economic and Social Studies Division, Mekong Secretariat Position Paper on the Pulp and Paper Industry in Thailand. MKG/WAID/28 (November 4, 1973).

Grade	Estimated Projections of Consumption 1970-1985			
	(-,000 MT/Year)			Annual Growth Rate (%)
	1975	1980	1985	
Printing & Writing Papers	57.3	73.3	93.9	5.1
Newsprint	59.8	81.7	110.6	6.3
Kraft Paper	38.8	58.0	84.6	8.1
Other Industrial Paper	97.7	143.8	207.2	7.8
Tissue Paper	14.0	20.4	28.7	7.5
Other Paper	8.7	12.5	17.7	7.4
Total	276.3	389.7	542.7	7.0 Av.

Source: (178) Phiphit S., Long-Term Projections of Demand and Supply of Pulp and Paper in Thailand. ASRCT Appraisal Report No. 27 (1974).

Grade	Estimated Projections of Consumption 1975-2000			
	(-,000 MT/Year)			
	1975	1980	1985	2000
Newsprint	70.0	110.0	180.0	600.0
				9.0

Source: World Bank quoted by (187) Business Rev. (Thailand) 2, no. 3:116-20 (January, 1974).

inadequate fibrous raw material supply from both wood and nonwood plant fibers, the growing high capital investment for building pulp and paper mills, and the increasingly higher costs for imported pulp and paper requiring the consequent payout of foreign exchange.

Therefore, the Consultants believe that the data developed by this study for the possible use of kenaf paper pulp are conservative and that the predicted annual growth rate of 3.5 percent for consumption of kenaf paper pulp, or the paper products which could be made from it in the Mekong project mill, should not be exceeded in planning such an enterprise within the foreseeable future.

5.5. The Possibilities of Export Markets for Kenaf Paper Pulps as Related to Technical Qualities and Future World Demand for Paper and Paperboard

As discussed in Section I.3. of this Study, the technical properties of the bleached and unbleached kenaf whole stalk and bast ribbon full chemical soda and sulfate pulps make them entirely suitable replacements respectively for the corresponding grades of hardwood or softwood sulfate pulps for many major grades of paper and paperboard. There are no competitive technical reasons that would prevent the sale of a considerable portion of the output, particularly the bast ribbon pulp grades, from a Mekong Basin kenaf paper pulp mill to the pulp purchasing countries in East Asia in the future.

From the standpoint of costwise competition, bleached whole stalk kenaf market pulp from the Mekong Basin countries will have to be exported at a delivered price matching the expected lower manufactured cost bleached hardwood pulps that will be produced in several larger productive capacity mills that are expected to be built in the South Pacific-Asia area within the next few years. As discussed in Section I.4.2. of this Study, these large hardwood pulp mills of at least 700 to 800 tpd. pulp capacity will not only have the benefits of "economy of size" but their fibrous raw material cost for mixed tropical hardwoods will probably run about half the cost per ton of finished bleached pulp product to that cost for kenaf whole stalk at the Mekong Basin project mill. Eventually, when these hardwood pulp mills switch over to eucalypts and other fast growing species from plantations, they will still be expected to have a somewhat lower cost base for fibrous raw material than for kenaf whole stalk grown and harvested under present conditions in the Mekong Basin area.

The kenaf ribbon pulp, even though based on a higher cost raw material than the kenaf whole stalk or bagasse pulps, would appear, under certain conditions, to be in at least as good if not better position to compete pricewise with softwood pulps in the market than kenaf whole stalk pulp will be to compete with hardwood pulps that can be produced within this export area. This will be the case if a process can be successfully developed for dry separation at the mill of the bast ribbon fraction from the field dried kenaf stalks as discussed in Section 4.3 of Chapter I. Alternately, the use of the woody core material, available at a relatively low cost from the ribboning operations discussed in Chapters V and VIII, would also furnish considerable economic benefit to the Mekong project mill by making this cellulosic waste material available for fuel or the production of mechanical pulp for newsprint.

This conclusion has also been reached based on the judgement that the natural growth of long fibered woods in this area is of limited volume and that it will be at least another 20 years before an appreciable start will have been made to establish the additional plantations of softwoods needed to supply future requirements. It appears therefore that, eventually, a shortage of long fiber pulp will develop in this possible market area. In addition, supplies of softwood pulp available from North America and Scandinavia will become more limited as those areas increase their own consumption of paper products and greater integration between pulp and paper mill is achieved. Increasingly high wood and labor costs in and the extra cost for transportation of softwood pulp from those areas to paper mills in the export area that could be served by the Mekong Basin project mill all tend to reduce the advantage of "economy of size" of the large softwood market pulp mills in comparison to the project mill of this Study.

All of these factors will eventually result in a greater differential in price than today's between bleached hardwood market chemical pulp and bleached softwood chemical pulp in the possible export area, when and if the several presently discussed large mixed tropical hardwood pulp mills come on stream and provide quantum jumps in short fiber pulp production capacity at low wood cost. If this happens, the higher cost for kenaf ribbon for pulp to compete with softwood pulp, as compared to kenaf whole stalk pulp competing with hardwood pulp, would partially be justified. This is, as stated above, dependent upon development of a process for successful separation from field dried kenaf stalks of woody core material and bast ribbon at the pulp mill and the utilization of the woody core fraction for fuel or the manufacture of mechanical pulp for newsprint.

Assuming that export markets outside the riparian countries for the kenaf paper pulp mill located in one of the Mekong Basin countries would be desirable or even needed from the standpoint of the enterprise as sized for this project, consideration must be given to the potential growth in demand for paper and paperboard in the world and specifically in Far East Asia, the area for potential exports from the project mill. Keays (195) has recently published estimates of the future demand for paper and paperboard shown in Table I.14. and a breakdown of demand by major geographical areas of the world as shown in Table I.15. These estimates of world paper and paperboard demand at years 2000 and 2020 are much lower than the projected consumption figures previously reviewed several years ago by the Consultants (196). It appears that unless some unlimited and low cost source of energy

Table I.14.

Projected Future World Demand for Paper
and Paperboard to Year 2200

Year	Assumed Annual Growth Rate (%)	Annual Demand for Paper & Paperboard (-,000,000 MT)
1965	5.00	100
1970	4.90	120
1975	4.80	150 (165)
1980	4.70	190 (210)
1990	4.50	280 (300)
2000	4.30	400 (415)
2010	4.10	570
2020	3.90	800
2050	3.30	1,800
2100	2.30	4,600
2150	1.30	9,800
2200	0.30	16,000

Note: This table gives the long range potential demand for paper and paperboard to the point where demand levels off in year 2219. Figures in () were projected from 1951-1973 world production of paper and paperboard.

Source: (195) Keays, J. L., Tappi 58, no. 11:90-5 (November, 1975).

Projected World Demand for Paper and Paperboard
to Year 2000 by Major Regions

Region	Annual Demand for Paper and Paperboard (-,000,000 MT)					Overall Growth Rate 1965-2000 (%)
	1965	1970	1975	1980	2000	
North America	43.6	52.3	61.7	72.0	150	3.6
Europe	28.7	37.9	47.6	59.3	95	3.5
Asia	14.3	20.6	29.0	40.3	85	5.2
USSR	5.3	8.3	12.4	18.1	50	6.6
Latin America	3.4	4.8	6.7	9.4	20	5.2
Africa	1.2	1.7	2.5	3.6	10	6.2
Pacific	<u>1.3</u>	<u>1.5</u>	<u>1.9</u>	<u>2.4</u>	<u>5</u>	<u>3.9</u>
World Total	<u>97.8</u>	<u>127.1</u>	<u>161.8</u>	<u>205.1</u>	<u>415</u>	<u>4.2</u>

Source: (195) Keays, J. L., Tappi 58, no. 11:90-5 (November, 1975).

Table I.15.

available to all areas of the world, particularly in the developing nations, is discovered and the annual increase in cost of building pulp and paper mills which has escalated so rapidly over recent years, is reduced to a more reasonable level, the world production of paper and paperboard in year 2000 will be considerably below the demand of 415 million tpy. that Keays has projected.

It should be considered that these projections show that the demand for paper and paperboard in Asia should increase by 11.3 million tpy. between now and 1980. This is the soonest the Mekong Basin project mill could start if the feasibility study and mill construction were to follow this Study, beginning immediately, in the normal orderly fashion. To supply this increase in demand would require building pulping and papermaking capacity equivalent to 162 mills of the product output capacity of the Mekong Basin project mill. To supply the additional 56 million tpy. demand that has been projected by year 2000, which is at only half the estimated reasonable life span of the Mekong Basin project mill if it started operating by 1980, would require 800 such projects of equivalent size in Asia.

The Consultants do not believe that these paper product demand growth rates, particularly the 5.2 percent for the overall area of Asia, will be achieved. There are too many constraints from the standpoints of fibrous raw material supply, the availability of capital that can be diverted to the paper industry in view of the competition for it with other industries required to meet national priorities, and the high cost and shortage of fuel. Also, the requirements for building the industrial machinery and for technical manpower are so great to meet such demands that it is doubtful such production levels for paper and paperboard could ever be met on this schedule.

However, in spite of the conservative judgement of the Consultants that world production of paper and paperboard will be doing well if the overall annual growth rate exceeds 3.5 percent during this period, there is no question but that the kenaf paper pulp, or even more so the paper and paperboard that could be produced on the same equipment, would find export markets in that geographical area due to an anticipated shortage in productive facilities in the long run.

Again, it should be emphasized that a combination kenaf whole stalk and bast ribbon chemical paper pulp mill built to supply the riparian countries of the Lower Mekong Basin would not be expected to have to find export markets outside those countries by 1980 unless there is a prior internal supply established from large integrated pulp and paper enterprises that might be developed in Thailand to use bamboo and bagasse as the fibrous raw materials. Apart from possibly lower production costs for the integrated bamboo-bagasse mill making paper rather than pulp only, the possibility of such an internal competitive situation for markets is viewed as being a serious constraint on the building of the kenaf project mill for operation only as a pulp mill for any extended period of years, when it could be manufacturing finished paper products from slush pulp. It is important that plans for implementing any further pulp and paper projects in the riparian countries give this important factor full weight in their considerations and that investment decisions be made in the best national interests to reduce the present expenditure of foreign exchange for pulp and paper imports as quickly as possible.

6. Choice of Products, Capacity, and Location for a Kenaf Paper Pulp Mill in the Mekong Basin

6.1. Grades and Types of Kenaf Pulps to be Produced in the Model Mill

For obvious technical reasons known to pulp and paper manufacturers throughout the world and because of the future anticipated pulp requirements of the Mekong Basin paper industry, there are certain potential grades of kenaf pulp that should be eliminated from detailed consideration for this pre-feasibility study for a paper pulp project. Such grades of commercial pulps are identified and the pulping process is defined by the name used for them in the following text.

Semichemical or neutral sulfite pulps from kenaf whole stalk or bast ribbon would not be as acceptable for bleachable grades as the full chemical soda or sulfate pulps which would be expected to have lower final production costs and higher paper strength properties. The organic materials that must be removed in bleaching the higher unbleached yield semichemical pulp are also greater than for full chemical cooked pulps and this requires more extensive effluent treatment facilities. The greater loss of organic material to waste disposal from bleaching semichemical pulp, rather than its recovery for its fuel value from spent cooking liquor from the full chemical cook processes, also represent a heat loss to the mill system.

Full chemical cooked acid or alkaline sulfite kenaf pulps would have several disadvantages in manufacturing and no advantages for final product quality as compared to the conventional soda and sulfate process pulps. Oxygen-alkali processes for the production of bleachable grades of pulps have not been developed to the point that would warrant their consideration for full scale application on kenaf at this time. Production by this method is not expected to show any advantages over the conventional soda or sulfate process chosen for the mill model for this Study. Polysulfide pulping is a variation of the sulfate process and could easily be incorporated in any mill built to use kenaf, if advantages are ever proved for it.

From the cost standpoint, the manufacture of unbleached semichemical pulp from kenaf for use in low cost corrugating medium or building papers would require that finished paper, rather than dried pulp, be manufactured. To dry the pulp for use in a

non-integrated mill would, in most cases, make the selling cost of these end products higher than they would be if made from waste fibers. These grades of paper can also be manufactured satisfactorily from another low cost fiber, bagasse, which is readily available in Thailand. They can also be produced from inexpensive, low quality grades of mixed waste papers. Furthermore, recently developed techniques have made it possible to separate the corrugating medium fraction of waste corrugated boxes from the linerboard fraction. This permits the recycling of each component into its original grade from small repulping systems located at existing paper mills which do not have pulp manufacturing facilities. Separating the linerboard fraction results in upgrading its strength properties, as compared to that of the mixed fiber in the original waste paper. Therefore, this particular secondary fiber pulp could replace a considerable portion of the imported unbleached softwood pulps used in the manufacture of linerboard and bag grades in the Mekong Basin paper mills.

For the present study, the most important alternative that can be considered to the use of kenaf for soda or sulfate full chemical pulps would be to manufacture mechanical pulp or the variations of this grade known as thermomechanical and chemimechanical pulps. The mechanical pulp would be produced by grinding in a disk refiner the chips of the wet cleaned whole stalk or of the woody core fraction of the kenaf. This is similar to the process for manufacturing the chip groundwood pulp from wood that is used in newsprint and in low grade printing and writing papers and some that are to be clay coated. Heating the kenaf chips before refining would result in power savings and probably give a somewhat stronger fiber product, as it does with wood, and which is called thermomechanical pulp. A somewhat similar improvement would also be achieved by a light chemical treatment of the kenaf with sodium sulfite or caustic soda solutions before the refining step and this product is known as chemimechanical pulp. These pulps would be bleached either during or after the refining step, depending upon the degree of brightness increase desired and the bleaching agent that would be used.

The mechanical pulps from kenaf that would be produced in the Mekong Basin area would most likely find their greatest utility and value in the manufacture of newsprint at the point of lowest cost pulp production. It would be much more costly to manufacture the pulp and dry it and ship it to another mill for making paper than to make the newsprint and other grades of paper in an integrated mill.

The conventional processes to manufacture these grades of paper consisting of a high mechanical pulp proportion of the fibrous furnish, probably as high as 80 to 90 percent for newsprint, require the addition of the balance of the furnish as semi-bleached long fibered chemical pulp in order to meet the paper strength requirements for high speed, web-fed printing press operation. This chemical pulp could be semi-bleached sulfite or sulfate softwood pulp or it might be semi-bleached kenaf whole stalk or bast ribbon soda or sulfate pulp. The softwood pulp would have to be imported but the kenaf chemical pulp could be manufactured in the Mekong Basin area, preferably at the site of the newsprint mill. To be economically viable, this would require a larger full chemical kenaf pulp mill than would be needed for the newsprint mill alone.

There is one important factor with regard to the use of kenaf for newsprint that has generally been overlooked. Usually the recommendations have been to use the woody core material for the mechanical pulp part of the furnish and to add the necessary long fibered chemical pulp to achieve the necessary final paper strength properties. It would appear that serious consideration should now be given to the possibilities for using the whole stalk kenaf, with or without some added bast ribbon, for producing a mechanical, thermomechanical or chemimechanical pulp of improved strength properties that could be used for up to 100 percent of the fibrous furnish for newsprint. The techniques are currently being developed for making stronger grades of mechanical pulps from softwoods which will be suitable for newsprint manufacture without the addition of chemical pulps.

There is a good possibility that these technical developments in mechanical pulping can be applied to making newsprint from kenaf. However, at the present time, so many problems remain to be investigated that the Consultants judge it unwise to base this entire Study using a single model mill on a newsprint project.

It would be more realistic to use the kenaf woody core residual material from textile fiber production or the bagasse available in other areas of Thailand to manufacture the conventional mechanical, chemimechanical, or thermomechanical pulp portion of the furnish for newsprint or other groundwood-containing types of papers. The kenaf chemical pulps, either from whole stalk or bast ribbon, would be more valuable in replacing the hardwood and softwood chemical pulps imported by the Mekong countries' paper mills at present or as the chemical pulp portion for the furnish in a newsprint mill that would be built later on.

In consideration of these factors, the decision has been made by the Consultants to plan in this Study for a single model mill to produce full chemical cooked grades of unbleached and bleached papermaking pulps using the soda or sulfate process. The choice of pulping process - full soda, full sulfate or a mixture in between - will depend upon which of the make-up chemicals - sodium hydroxide (caustic soda), sodium carbonate (soda ash), or sodium sulfate (salt cake) - is the lowest in cost based on its sodium ion content. This ignores any consideration, for the time being and until they can be established in pilot scale operation, of possibly slight differences in pulp quality and yield that might result from the use of a full soda or full sulfate cook in continuous digester systems.

On the basis of published data, the proposed grades of pulp can be made in the project model mill in three basic types. They are defined as kenaf whole stalk pulp, bast ribbon pulp, or a mixture in between, tailored to meet the customer's requirements. These pulps are considered entirely suitable, depending upon the fiber composition used and either alone or in admixture with other pulps, for the manufacture of unbleached grades of paper such as grocery bags and wrapping paper, multiwall bag paper, linerboard, folding boxboard, and industrial converting papers. The bleached grades of these types of pulps would be suitable for food board and milk carton stock, uncoated and coated printing papers and boards, writing papers, and tissue and towelling grades.

Therefore, the model mill designed for this project could supply, within a few years, a wider range of pulp types and grades needed by the existing paper mills of the Mekong Basin countries than could be produced from any single species of wood or any of the major nonwood plant fibers such as bagasse or straw that are now used for papermaking. Eventually, when the market requirements are favorable, the same mill could convert the pulp drying machine very easily, and at a very low additional investment, to the manufacture of several of the major grades of finished paper thereby achieving the final maximum economy of scale and integration envisioned by the Consultants in the original project planning.

6.2. Model Pulp Mill Capacity

For any specific project, there are many factors to be considered that ultimately determine the size of pulp mill to be built. The general rule of thumb has been that the larger the pulp mill that can be built and operated at full capacity, the lower the total investment and operating costs and the higher the efficiency, all on the basis of each ton of product. This "economy of scale" has resulted in the building, in recent years, of single line wood pulp mills producing bleached hardwood and softwood market pulps in the size range of 700 to 1,000 tons per day (tpd.) of product and the planning for nonwood plant fiber pulp mills of capacities in the size range of 350 to 500 tpd. of bleached market pulp. There is also the very serious and continuing escalation, all over the world, of pulp mill building costs, particularly greater percentagewise for the smaller units and for the developing nations who have to purchase the necessary sophisticated papermaking equipment on the world machinery market. This equipment cost escalation keeps automatically pushing projects under consideration into a larger size range wherever markets favor and raw material supplies allow.

In the case of kenaf for paper pulp, there is an excellent historical example of this situation relating to investment and size escalation as it has developed in one of the Mekong riparian countries. The project development history of the United Pulp and Paper Co., Ltd. (200) in Thailand indicates that, at the September 1970 UNIDO/ECAFE conference in Manila, a report (201) was given on a feasibility study for a 100 tpd. whole stalk kenaf bleached pulp mill. Early in 1971, a news item (202) reported that the mill would be located in Khon Kaen Province and would require a total investment of ¥336 million (US\$16.8 million). In October 1972, another magazine (209) reported the same investment figure but for a 150 tpd. mill to be located in the Saraburi area. By August 1973, it was stated (200) that the estimated investment had reached ¥500 million (US\$25 million) for the planned capacity of 150 tpd. There is no further information available that would indicate what the final cost estimate for building this mill was by 1974 when, according to the Thailand Board of Investment (BOI), the Certificate for this projected enterprise expired.

It is quite obvious from these data on production and investment requirements that the factors of economy of size and cost escalation were encountered and recognized by the promoters of the project as they got further along in the planning. There is also an indication that, as the project was studied more thoroughly, it was necessary to

add many costly features which were not considered in the pre-feasibility study.

It is interesting to note that the BOI recently told the Consultants that approval has been granted for a new project by Phoenix Pulp & Paper Co., Ltd., for a 50,000 tpy. bleached whole stalk kenaf pulp mill. A recent newspaper report (207) listed this pulp project for 70,000 tpy. as costing ¥1,000 million (US\$50 million) with 25 percent of the capital cost as equity and the rest made up of suppliers' credits. Vira (210) has reported that this increase in tonnage also raised the investment anticipated from an original US\$36 million and that this mill would use kenaf and rice straw to produce 60 percent short fiber and 40 percent long fiber pulps.

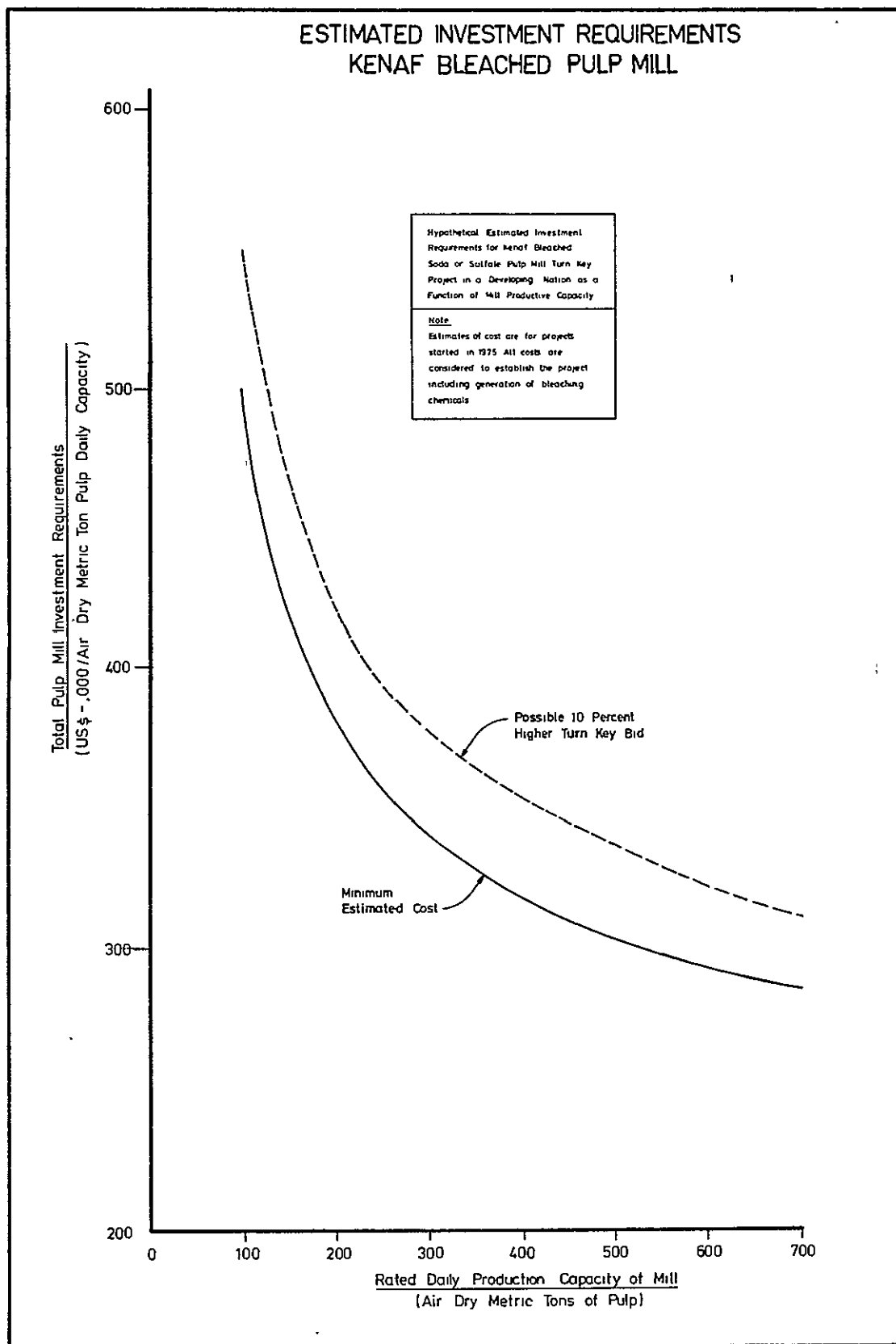
The problem of economy of size is one which has always been of great concern in planning the building of pulp and paper mills, particularly in developing areas of the world. Some of the earliest FAO studies and meeting papers emphasized the high cost per unit of productive capacity for a small pulp or paper mill as compared to larger ones. A Secretariat Paper (203) at the FAO meeting in Tokyo in 1960 clearly showed the rapidly increasing investment required, even for that time, per unit of pulp mill productive capacity as the daily tonnage rate was decreased below 200 metric tons of pulp per day.

This factor of economy of size for various types of pulp and paper mills has been clearly shown more recently by Eklund and Kirjasniemi (204) and FAO (205). Investment cost data for nonwood plant fiber pulp and paper mills of various productive capacities and product types have also been developed by Krauss-Maffei AG. (206). However, when using the above data for actual cost estimates, it must be considered that today's costs would be considerably higher.

The advantages of economies of size of an installed pulp mill for fixed investment and production costs have also been clearly shown in a recent study for the Economic Commission for Asia and the Far East (ECAFE) (208). It is interesting to note that this report shows the investment cost advantage of the integrated vs. the nonintegrated mills for capacities above 80,000 tons per year.

The economy of size in building pulp mill projects is clearly illustrated in Fig. I.2. developed by the Consultants. The data in the figure are based on recently quoted prices for "turn key" project pulp mills of various sizes and utilizing nonwood plant fibers in developing countries as well as on updated estimates from the prior

Fig. I.2.



studies noted in the foregoing. The figure shows the hypothetical estimated investment requirements, including the possibility of a 10 percent higher turn key bid, for various sizes of bleached kenaf soda or sulfate pulp mills.

These mills would be built as turn key projects of the most modern and proper design, including the scope of training and startup management services considered necessary for the establishment of the Mekong project model mill. This project mill would be designed to produce the full range of pulp types from kenaf whole stalk pulp to pulp from bast ribbon, including any mixtures in between. This economy of size resulting from building a large single line mill has the effect of decreasing the total manufacturing and overall operating costs per ton of product, such as for depreciation and interest, sales and management overhead costs, labor costs, repairs and maintenance materials and, to a lesser extent, for the mill consumption of chemicals and the use of utilities, as well as for taxes and insurance. The unit consumption of fibrous raw material and the transportation costs are about the only items which do not appreciably benefit from a larger scale project.

There are several specific factors and conditions which can have a levelling or compensating effect on the economy of scale factor. One of the most important is a limitation imposed by the size of the pulp/paper market that can possibly be served at a profit and/or on a national interest basis to conserve foreign exchange, utilize local raw materials, and furnish employment. Another major factor limiting pulp mill size can be a physical limit on raw material supply or a balancing of the economy of scale advantage by an increasing delivered cost per unit of fibrous raw material resulting from harvesting it from a greater area with higher average costs for transporting it for greater distances. An additional inhibiting factor might be the amount of total capital investment required for a larger mill when national interests may favor or require alternative investments in other industries. Finally the mill size might be limited by reduced seasonal flow of the receiving stream used for effluent disposal, even where advanced waste treatment systems are used.

After considering all of these factors and the data on pulp markets, kenaf supply, pulp imports, etc., collected and studied by the Consultants, it has been concluded that the model mill for this project for kenaf for paper pulp in the Mekong Basin area should have a nominal productive capacity of 200 air dry metric tons (ADMT) per day of bleached whole stalk kenaf pulp or 70,000 ADMT/year for a

maximum operating period of 350 days per year. For design purposes for the fibrous raw material supply, it has been assumed that this will be the amount produced annually of either or both of the two types, bleached kenaf whole stalk or bast ribbon pulp, as well as any combination of the two. The filtering area of the pulp washing systems to remove spent cooking liquor and bleaching residues from the pulp will be designed and sized to operate at the normal design rate of 200 ADMT/day on the more slowly draining whole stalk kenaf pulp. However, it must be realized that the pulp washing equipment could handle considerably more of the more rapidly draining pulp made from kenaf bast ribbon and a somewhat higher production rate could be achieved in actual practice. Also, for the same fibrous raw material consumption, the productive capacity of the mill at designed conditions would be about 10 percent higher for the unbleached grades than for the bleached grades.

In conclusion, it must be emphasized again that the choice of a 200 ADMT/day pulp mill has been made on the Consultants' assumption that this will be a minimum size for determining the economic viability of the project and that it would allow an estimate to be made of the profitability of a larger mill if sufficient fibrous raw materials are available and pulp or paper consumption could absorb additional production.

6.3. Locating Pulp Mill Sites in the Mekong Basin

From the standpoint of supply on future pulp consumption and, later, on paper consumption, the Mekong Basin area of the Northeast of Thailand would be the most logical first choice for the kenaf pulp mill location since Thailand offers the largest market. Based on communication and transportation facilities (particularly railroads), domestic supplies of fuel and chemical raw materials, electric power and general infrastructure, and on an operating paper industry of considerable size, a Thailand location is predominately favored by these factors. However, consideration has been given by the Consultants to possible sites for pulp mills located in the other Mekong riparian countries, even though it was not possible to visit those outside Thailand at the time of the field survey.

6.3.1. Potential Mill Locations Based on Water Availability

The site chosen for a pulp/paper mill requires an adequate supply of surface water from lakes or rivers or of ground water from wells. Also required nearby is a river of appreciable flow for dilution and disposal of the properly treated effluent from the mill. In cases where rivers have large flows for part of the year during the rainy season but very low flows in the dry season, some sites can be used if impounding basins are filled with effluent during the dry season and this is released and can be adequately diluted when the river flow is higher. Certain portions of the effluent can also be segregated within the mill and used for irrigation. In addition, the pulp mill must be designed for maximum practical recycling of water within the mill. It is understood that pulp mill effluent does not contain sewage from sanitary systems that has not been properly treated for discharge to water courses and there would be no poisonous chemicals present, such as mercury. The liquid effluent leaving the pulp mill before treatment would contain organic materials dissolved from the kenaf in wet cleaning the fiber, some suspended fiber fines, and sodium chloride (common salt) and organic compounds of these two ions resulting from pulping operations. The losses of chemicals in the liquid and gaseous effluents from the pulping operation would be minimized by an almost completely closed recovery system for the spent pulping liquor.

Final treatment of the effluent prior to disposal would result in removal of most of the fibers and other suspended solids and oxidation by aeration of the oxygen-consuming soluble substances removed from the kenaf in processing the raw fiber to pulp. The treated effluent would not only be suitably diluted by the receiving waters in the river but would meet the general requirements for quality established by the pollution control authorities for the Mekong Basin country in which the plant would be located.

With these primary requirements in mind, consideration has been given to the selection of potential pulp mill sites in the Mekong watershed area where kenaf could be made available and there would be a sufficient water flow in the river for mill supply and for required dilution and disposal of the treated mill waste effluent. The possible use of ground water has not been fully investigated in this study because data for that part of the Mekong Basin area which is located in Thailand, where the best sites are situated, indicate that underground supplies of water of sufficient quantity for the mill would be costly and difficult to establish.

Based on stream flow data from the Lower Mekong Hydrologic Yearbook for 1973 (211) for the various rivers, sites were considered at the following locations:

Mekong River

- (1) Nong Khai, Thailand
- (2) Khong Chiam (Ban Dan), Thailand
- (3) Pakse, Laos
- (4) Stung Treng, Cambodia
- (5) Kratie, Cambodia
- (6) Chhlong, Cambodia
- (7) Kompong Cham, Cambodia
- (8) Phnom Penh, Cambodia (possibly on Bassac River)

Stung Sanke River

- (9) Battambang, Cambodia

Nam Pong River

- (10) Ubolratana Dam (Khon Kaen), Thailand

Nam Chi River

- (11) Kosum Pisai, Thailand
- (12) Yasothon, Thailand

Nam Takong River

- (13) Lam Takong Dam (Korat), Thailand

Nam Mun River

- (14) Tha Tum, Thailand
- (15) Ubon Ratchathani, Thailand

Se Bang Fai River

- (16) Se Bang Fai, Laos

Se Bang Hieng River

- (17) Bang Keng Done, Laos

Dak Bla River

- (18) Kontum, Viet-Nam

Ea Krong River

- (19) Drayling, Viet-Nam

Se Kong River

- (20) Ban Khumuon, Cambodia

Se San River

- (21) Ban Komphun, Cambodia

Sre Pok River

- (22) Lomphat, Cambodia

Many of these locations were found to meet the requirements of sufficient river flow for mill water supply and effluent disposal. The water analysis data indicate that, after treatment, the water at all locations would be suitable for the manufacture of high brightness bleached market pulp and paper. However, when consideration was given to the other major requirements for a pulp mill site, it was found that most of these potential locations could be discarded in this initial screening to locate sites for the model mill.

6.3.2. Potential Mill Locations Based on Technical, Sociological, Economic and Ecological Requirements

The major criteria for choosing a potential pulp mill location, apart from an adequate and economical supply of fibrous raw material nearby, favor a basic established area infrastructure, communication and transportation (air, rail, and truck) facilities, adequate water supply and waste effluent disposal means, accessibility to chemicals and fuel, a nearby electric grid for start-up and standby power, a pool of skilled and unskilled labor, and the municipal facilities provided by a nearby city. For the actual site, a large, well drained, easily accessible and level area of land above maximum flood level is needed. Using these requirements as a basis for rating the potential sites first indicated by the river flow data, it has been determined that there are a total of six potential pulp mill sites in the Mekong Basin that can seriously be considered and rated for suitability. They are shown on Plate I.1. where the circles on the map indicate the potential area of kenaf whole stalk or bast ribbon supply for each mill site.

It should be recognized that the numbers indicating the sites were chosen by geographical location and have no meaning as a rating of the sites for their suitability for a paper pulp mill. Unfortunately, the Consultants could not make an inspection of the potential sites outside of Thailand at the time of the field survey. However, on the basis of information collected and analyzed by the Consultants, it appears reasonable to divide the potential locations into the two categories of primary and secondary sites. This will allow the development of a model mill project for the primary sites and enable the Consultants to determine the viability of a kenaf for paper pulp project.

Potential Kenaf Pulp Mill Locations in the Riparian Countries

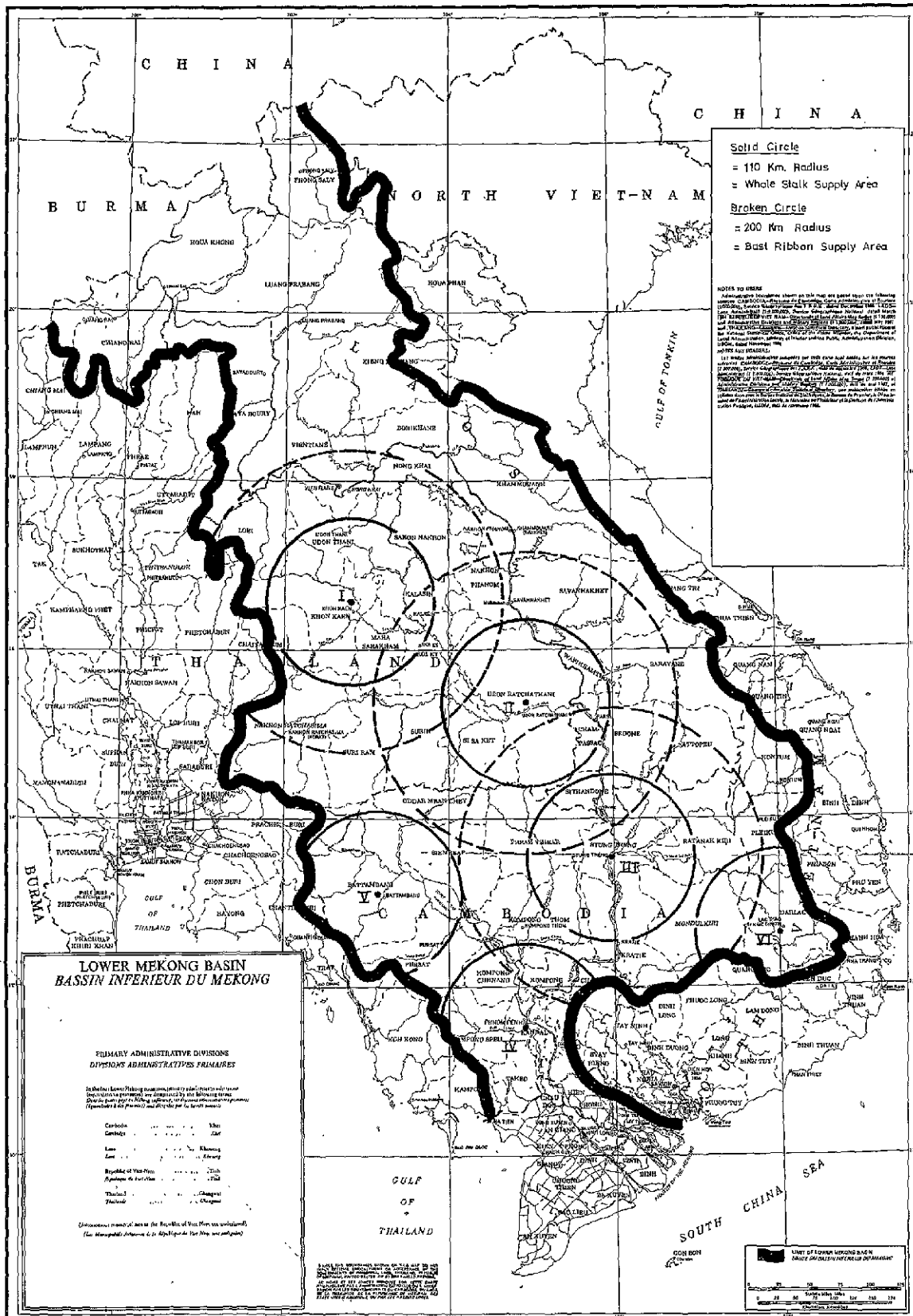
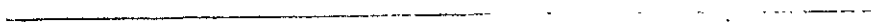


Plate I. 1.



It is interesting to note that, about ten years ago, a pulp/paper project survey was prepared for the Committee for Coordination of Investigations of the Lower Mekong Basin by the Nordic Group (212). In this study, a survey was made for potential sites for pulp/paper mills in the Lower Mekong Basin. These mills were planned to utilize some wood from natural forests but would be based primarily on a wood supply from plantations to be established. It was concluded by the experts that the Phnom Penh area or the zone between Ubol (Ubon Ratchathani) and Pakse would have the best possibilities for mill sites when chosen on the basis of factors other than supply of fibrous raw materials.

PRIMARY POTENTIAL MILL SITES

Site I. A potential area for mill sites has been located and examined in the Ubolratana Resettlement Area of the Province of Khon Kaen in Northeast Thailand. There are at least two potential sites about 35 to 40 km. north of the town of Khon Kaen along the banks of the Nam Pong River between the Ubolratana Dam and the Friendship Highway running parallel to the railroad.

At this location, the pulp mill would pump the initially estimated 0.50 cu.m./sec. of water required from a 39 million cu.m. lake between the Ubolratana Dam and the barrage built across the Nam Pong River several kilometers downstream. The barrage serves the purpose of forming a reservoir to hold water for a considerable period when the water turbines at the dam may not be operating and from which a continuous flow of water (15 cu.m./sec.) is diverted to Khon Kaen Township for domestic and industrial use. Eventually, another water flow (35 cu.m./sec.) will be diverted to the Nong Wai irrigation area that is being developed. Information from the Electricity Generating Authority of Thailand (EGAT) and the Royal Irrigation Department (RID) indicates that future plans call for the release of sufficient water for power generation from the dam into the lake during the turbine operating periods to assure an average daily minimum flow of water throughout the year of 55 cu.m./sec. into the lake above the diversion barrage. Besides supplying the two diversions already mentioned, this would insure an average minimum water overflow of 5 cu.m./sec. on down the Nam Pong River below the barrage. In this situation, the waste effluent, amounting to approximately the 0.50 cu.m./sec. volume of the water intake to the mill, would have to be disposed of in the water for the irrigation scheme or in the river below the barrage or both.

It would not be the most desirable plan to add the pulp mill's waste effluent to the water diverted to Khon Kaen Township, even though it would be relatively highly purified and would contain no harmful chemicals or bacteria from human sewage.

A study by the Consultants of the records for total water inflow and outflow for the Ubolratana Reservoir shows that, for a 9 year period starting in 1966, the average inflow rate was about 55 cu.m./sec. and the average outflow about 37 cu.m./sec. However, the critical factor from the pulp mill standpoint is what will actually happen to the outflow allowable during years of low rainfall. The EGAT reports show that, in the entire period, the reservoir outflow rates on a monthly averaged basis ranged from 4.81 to 121.96 cu.m./sec., with the overall average being 37 cu.m./sec. For a year of low rainfall, 1973, the outflow rates of water from the dam ranged from 4.81 to 36.59 cu.m./sec. with an average of 12.4 cu.m./sec. This information indicates that there may be a problem for this site on the disposal of waste effluent during a prolonged dry period and the final feasibility study for the paper pulp mill would have to take this into account.

Eventually, processes that are under development for recovery of spent bleaching liquors to eliminate mill waste effluent may be commercially successful but the present model mill cannot be based on that probability. This site above Khon Kaen township does have some advantage over Site II at Ubon Ratchathani in that it requires a railroad spur of only about 5 km. length while the sites at Ubon Ratchathani would require a 15 to 30 km. addition to the railroad. Also, the railroad distance from Ubolratana to Nakorn Ratchasima at the junction to Bangkok is considerably less than that from Ubon Ratchathani to Nakorn Ratchasima, so that Site I also has a freight cost advantage.

However, the Consultants consider that the advantages of having the mill on a larger river and closer to a large city as well as the potential of a Mekong Basin regional supply of kenaf from adjacent areas of Laos and Cambodia for the Ubon Ratchathani location would equalize the advantage of freight differential favoring the Ubolratana location.

From the standpoint of fibrous raw material supply the Ubolratana location is in the center of a large traditional kenaf (H. sabdariffa) production area, as discussed in detail in the agro-economic sections of this report.

Site II. Ubon Ratchathani in the Province of Ubon Ratchathani in Northeast Thailand has been visited on the Consultants' field trip to the Mekong Basin area. An area near this town not only meets all the major requirements for a pulp mill location but is advantageously located upstream of where the Nam Mun River empties into the Mekong River and in the center of the Mekong Basin area. Location of a paper pulp mill here would allow farmers in the adjacent territories in Laos and Cambodia to participate in supplying kenaf to the mill, most likely in ribbon form. The Consultants have located excellent ground for sites at a distance of 15 to 30 km. east of Ubon Ratchathani where the railroad connecting with the rest of Thailand ends. Several attractive individual sites are located between the all-weather paved Highway No. 217 and the south bank of the Nam Mun River. At these locations, the river is quite large and navigable for at least part of the year. This would allow some kenaf ribbon to be hauled in by boat from the central reaches of the Mekong River.

Hydrologic data from the 1973 Lower Mekong Hydrologic Yearbook for the Nam Mun River at Ubon Ratchathani show an average discharge of 589 cu.m./sec. for the period 1956 to 1973. The maximum discharge recorded after 1944 was 5,560 cu.m./sec., and the minimum discharge after 1951 was 3.2 cu.m./sec. It appears from these data that the mill would have an adequate supply of river water at all times. However, in planning the waste effluent disposal system for the mill, a study would have to be made of the historical river flow data throughout the year to determine the variable storage capacity of basins at the treating plant required for impounding effluent during the periods of extremely low river flow that have occurred in years of low rainfall.

There is also an advantage to waste effluent disposal favoring the river below Ubon Ratchathani. Several tributaries flow into the Nam Mun between the potential sites and the point, less than 75 km. downstream, where it joins the Mekong River with its huge flow of water that has enormous waste assimilative capacity.

In addition to being near Ubon Ratchathani, a large town of considerable industrial potential, the sites are near a major power transmission line located along the highway.

Ubon Ratchathani is located within a large H. sabdariffa production area which also has a limited potential for growing H. cannabinus. It appears to be within economic transportation distance of potential kenaf production areas in neighboring Laos and

Cambodia, and thus would possibly allow farmers in these two countries to supply an appreciable part of the raw material for a regional Basin project. This is discussed in detail in the agro-economic sections of this report.

SECONDARY POTENTIAL MILL SITES

The rating of the following sites as being less desirable than the two primary sites previously discussed would not rule them out for investigation in a detailed feasibility study. In fact, the paper consumption of the Mekong riparian countries will eventually reach levels which may make it advantageous to establish additional pulp and paper enterprises based on kenaf at one or more of these secondary site locations.

Site III. Stung Treng, Province Stung Treng, Cambodia, is a potential pulp mill site on the Mekong River. There is access to this location by highway and the lower Mekong River but railroad transportation is lacking. It is also within a potential H. sabdariffa/H. cannabinus production area.

Site IV. Another possible site for the pulp mill would be Phnom Penh in the Province of Kandal, Cambodia. Although the actual site has not been inspected by the survey team, the flows in the Bassac or Mekong Rivers appear to be more than adequate for the needs of a pulp mill. This location near a large city is also favored by a railroad connecting into Thailand and it has an ocean port. It is also within a potential H. sabdariffa/H. cannabinus production area.

Site V. Battambang in the Province of Battambang, Cambodia, on the Stung Sanke River requires further investigation before it can be said to be suitable from the standpoint of water supply and waste effluent disposal. It is on the railroad between Bangkok and Phnom Penh and has road transportation as well. It is also within a limited past and large potential future H. sabdariffa/H. cannabinus production area.

Site VI. Drayling in Darlac Province, Viet-Nam, is located on the Ka Krong River which has an adequate flow of water. However, this location lacks rail and water transportation facilities. Although this location commands a limited past and large potential future H. sabdariffa/H. cannabinus production area, part of the surrounding potential zone of supply is outside the Mekong watershed. It would

appear that kenaf grown in this region would be more useful to supply existing or new pulp mills in Bien Hoa, Viet-Nam, which lies outside the Mekong Basin limits.

Note: From a recent news release (207), it appears that a site for a kenaf paper mill has been located by the Phoenix Pulp & Paper Co., Ltd., in the Ubolratana Resettlement Area north of Khon Kaen in Northeast Thailand (see Site I above).

7. Kenaf Raw Material Requirements and Supplies

7.1. Kenaf Raw Material Requirements

7.1.1. Kenaf Raw Material and Planting Area Requirements, Whole Stalk Kenaf Pulp Mill

In this Study, the term "Whole Stalk Kenaf Pulp" applies to pulp produced from 100 percent kenaf whole stalk raw material. The tonnage of such material required by a 70,000 ADMT/year whole stalk kenaf pulp mill is calculated as follows:

- 70,000 ADMT bleached pulp/year containing, by definition, 10 percent moisture = $70,000 \times 0.9 = 63,000$ ODMT pulp/year;
- At 35 percent bleached pulp yield (see Section 3. of this present Chapter I), kenaf whole stalk requirements = $63,000 / 0.35 = 180,000$ ODMT stalks;
- $180,000 / (1.0 - 0.125) = 205,714$ FDMT kenaf whole stalks at 12.5 percent moisture content.

The whole kenaf stalk yields per unit area, for both South Asian (H. sabdariffa) and Western Hemisphere (H. cannabinus) kenaf are discussed in detail in Chapter V, Section 3.2., of this Study. On the basis of the anticipated stalk yield ranges assumed in that section, the required kenaf planting areas, rounded off, will then be as shown in Table I.16. It will be seen that they range from a minimum of 10,300 ha. (25,750 acres; 64,500 rai) for H. cannabinus produced under favorable agronomic conditions to a maximum of 27,500 ha. (68,750 acres; 172,000 rai) for low average yields of H. sabdariffa.

7.1.2. Kenaf Raw Material and Planting Area Requirements, Kenaf Bast Ribbon Pulp Mill

In this Study, the term "Kenaf Bast Ribbon Pulp" applies to pulp produced from 100 percent kenaf bast ribbon raw material and the tonnage of such material required by a 70,000 ADMT/year kenaf bast ribbon pulp mill is calculated as follows:

Planting Area Requirements
70,000 ADMT/Year Whole Stalk Kenaf Pulp Mill

Species	<u>H. Sabdariffa</u>		<u>H. Cannabinus</u>	
Whole Stalk Yield * (FDMT/Ha.) **	7.500	9.375	15.000	20.000
Annual Whole Stalk Raw Material Requirements (FDMT)	206,000	206,000	206,000	206,000
Required Planting Area:				
Ha.	27,500	22,000	13,750	10,300
Acres	68,750	55,000	34,500	25,750
Rai	172,000	137,500	86,000	64,500

* H. sabdariffa - See Section V.3.2.1.

H. cannabinus - See Section V.3.2.2.

** FD = 12½% Moisture Content

- 70,000 ADMT bleached pulp/year containing, by definition, 10 percent moisture = $70,000 \times 0.9 = 63,000$ ODMT pulp/year;
- At 45 percent bleached pulp yield (see Section 3. of this present Chapter I), kenaf bast ribbon requirements = $63,000/0.45 = 140,000$ ODMT bast ribbon;
- $140,000/(1.0-0.125) = 160,000$ FDMT kenaf bast ribbon at 12.5 percent moisture content.

The percentage of kenaf bast ribbon in the whole stalk, for both South Asian (H. sabdariffa) and Western Hemisphere (H. cannabinus) kenaf, is discussed in Chapter V, Section 1. of this Study where it has been set, on the average, at 24 percent of the whole stalk. Based upon the anticipated whole stalk yield ranges already listed in Table I.16., the required kenaf planting areas, rounded off, to produce the necessary ribbon tonnage are then shown in Table I.17. where they vary from a low of 33,500 ha. (83,750 acres; 209,500 rai) for H. cannabinus grown under favorable agronomic conditions to a high of 89,000 ha. (222,250 acres; 555,500 rai) for H. sabdariffa grown under low average conditions.

Planting Area Requirements
70,000 ADMT/Year Kenaf Bast Ribbon Pulp Mill

Species	<u>H. Sabdariffa</u>		<u>H. Cannabinus</u>	
Whole Stalk Yield * (FDMT/Ha.) **	7.500	9.375	15.000	20.000
Kenaf Ribbon Content of FD Stalks ***	24%	24%	24%	24%
Ribbon Yield (FDMT/Ha.)	1.80	2.25	3.60	4.80
Annual Ribbon Raw Material Requirements (FDMT)	160,000	160,000	160,000	160,000
Required Planting Area:				
Ha.	89,000	71,000	44,500	33,500
Acres	222,250	177,500	111,250	83,750
Rai	555,500	444,000	278,000	209,500

* H. sabdariffa - See Section V.3.2.1

H. cannabinus - See Section V.3.2.2.

** FD = 12½ % Moisture Content

*** See Section V.1.

7.2. Kenaf Raw Material Supplies

7.2.1. Kenaf Raw Material Production Organization

In Northeast Thailand, kenaf production has been well established for more than 20 years as a small holder operation involving hundreds of thousands of farm families and this method of production will doubtlessly continue, including the production of kenaf for the envisaged pulp and paper industry. As to whether kenaf raw material will be produced by the small holders in Northeast Thailand - or anywhere else in the riparian countries - in sufficient quantities for the projected pulp and paper mill(s), this will depend primarily on the price offered to the grower for the raw material and on its profitability compared to that of the other crops he can grow on his land.

In this Study, reference will be made - in addition to Small Holder (Peasant Farmer) Kenaf Production - also to Nucleus Farm and Small Holder Operations, Commercial Plantation Operations, and Combined Small Holder and Commercial Plantation Operations (see Chapter III, Section 4.). Small holder kenaf production will, obviously, continue to be the method used in Northeast Thailand and will also be the predominant or exclusive method adopted in any future kenaf production program in the other riparian countries. However, any small holder production would greatly benefit from the type of nucleus farm program which will be discussed herein.

It is hardly likely that independent kenaf plantation operations will be set up in the Lower Mekong Basin area in future. Nevertheless, this type of operation will be dealt with in this Study and that because it is anticipated that any future kenaf pulp mill organization will wish to or will be required to organize a demonstration kenaf farm which, of necessity, would have to be organized along "commercial" lines and which could combine its operations with those of the small holders in the vicinity.

7.2.2. Kenaf Raw Material Purchasing Policies

The purchase of the kenaf raw material for the mills at the various projected locations will be subject to certain considerations which will vary with the mill site.

Mill Sites I and II are located in Northeast Thailand, the largest traditional kenaf producing area in the world. However, kenaf production in that area is presently geared to the requirements of the local bag mills and of the export trade. In order not to adversely affect the raw material supply to these two traditional markets, it will be assumed in this Study that only 25 percent of the potentially available kenaf crop grown in any specific area in the Northeast will be purchased by the pulp mill. Hence, in Northeast Thailand, from 41,200 ha. to 110,000 ha. (258,000 rai to 688,000 rai) of kenaf production areas would have to be accessible to a whole stalk kenaf pulp mill processing the entire kenaf stalk, and from 134,000 ha. to 356,000 ha. (838,000 rai to 2,225,000 rai) to a kenaf bast ribbon pulp mill processing kenaf bast ribbon only (see Tables I.16. and I.17.).

Similar competitive markets for kenaf raw material do not exist in the other three riparian countries, or at least only to a limited extent (1 bag mill in Cambodia, 2 bag mills in Viet-Nam, of which one closed down), so that it is assumed that 100 percent of any potential new kenaf production in those three countries would be available to the pulp mill(s). Hence, required production areas would be from 10,300 ha. to 27,500 ha. for a whole stalk kenaf pulp mill, and from 33,500 ha. to 89,000 ha. for a kenaf bast ribbon pulp mill (see Tables I.16. and I.17.).

CHAPTER II - HISTORY OF THE KENAF AND ALLIED FIBER INDUSTRY IN THE RIPARIAN COUNTRIES

1. Introduction

Kenaf is the common popular name of two closely related species of the family Malvaceae, namely Hibiscus cannabinus L. and Hibiscus sabdariffa L. var. altissima. The soft fiber contained in the bast (bark) of the kenaf stalks has properties very similar to those of jute fiber and has become an important substitute of jute, particularly during the last 25 years or so.

Kenaf is known under many different names in the various production areas, including "Mesta" and "Bimli Jute" in India and Bangladesh, "Teal" in Egypt, "Da" in Sub-Sahara Africa, and "Rosella" in Indonesia. In Thailand, it was referred to for many years as "Siam Jute" but is now generally called "Thai Kenaf".

Jute and jute-like fibers, such as kenaf, have long been of substantial importance in world commerce and industry, although strong competition is now being offered by some of the artificial fibers. They are used in burlap and other bagging materials, camouflage cloth, carpet and linoleum backing, tying cord, plastics, and many other applications. During and after the Second World War, jute fiber supplies became scarce and prices increased leading to a worldwide search for jute substitutes. It was found that kenaf fiber closely resembles jute and that the crop can be grown economically under a great variety of soil and climate conditions.

Hibiscus sabdariffa is cultivated principally in Bangladesh, India, Thailand and Indonesia, and Hibiscus cannabinus mostly in Africa and Latin America. Hibiscus sabdariffa will also be referred to in this Study as "H. sabdariffa" and "South Asian Kenaf", and Hibiscus cannabinus as "H. cannabinus" and "Western Hemisphere Kenaf". Basically, H. sabdariffa is the slower maturing and lower yielding but more drought and disease resistant species, whereas H. cannabinus matures more rapidly and normally produces greater fiber (and stalk) yields but requires somewhat better soil and climatic conditions.

Because of the extensive use of jute and jute substitute fibers in burlap and bagging, many of the developing countries which depend on large-scale agricultural production and thus require substantial quantities of jute and kenaf goods for the containers in which to transport their produce have established their own local fiber growing and bag manufacturing industries thus reducing foreign exchange expenditures on the importation of bagging fibers and bags as well as creating new sources of agricultural and industrial employment, helping to diversify agricultural production, and making the country strategically independent as far as its bagging fiber requirements are concerned.

Such developments have also taken place in three of the four countries of the Lower Mekong Basin, most particularly in Thailand where kenaf was introduced as a profitable cash crop for the poor soil conditions in the Northeast and has become not only the exclusive raw material for an important bag mill industry but one of the major export crops of the country. An intensive kenaf development program was also carried out in the Republic of Viet-Nam, particularly during the late 1950's and early 1960's but was later curtailed as a result of war-related conditions, and a similar although more limited program has been implemented in Cambodia somewhat intermittently during the last 15-year period. Laos is the only country in the region where no effort has been made towards the establishment of a local kenaf industry, obviously in view of its limited bagging material requirements, although some sporadic attempts have been undertaken to process an indigenous kenaf-like plant.

An overview of the history of the kenaf and allied fiber history in the four riparian countries is presented in the following sections of this chapter. Traditional kenaf and allied fiber production areas in the Lower Mekong Basin are shown in Plate II.1. on the following page.

Traditional Kenaf and Allied Fiber Production Areas in the Lower Mekong Basin

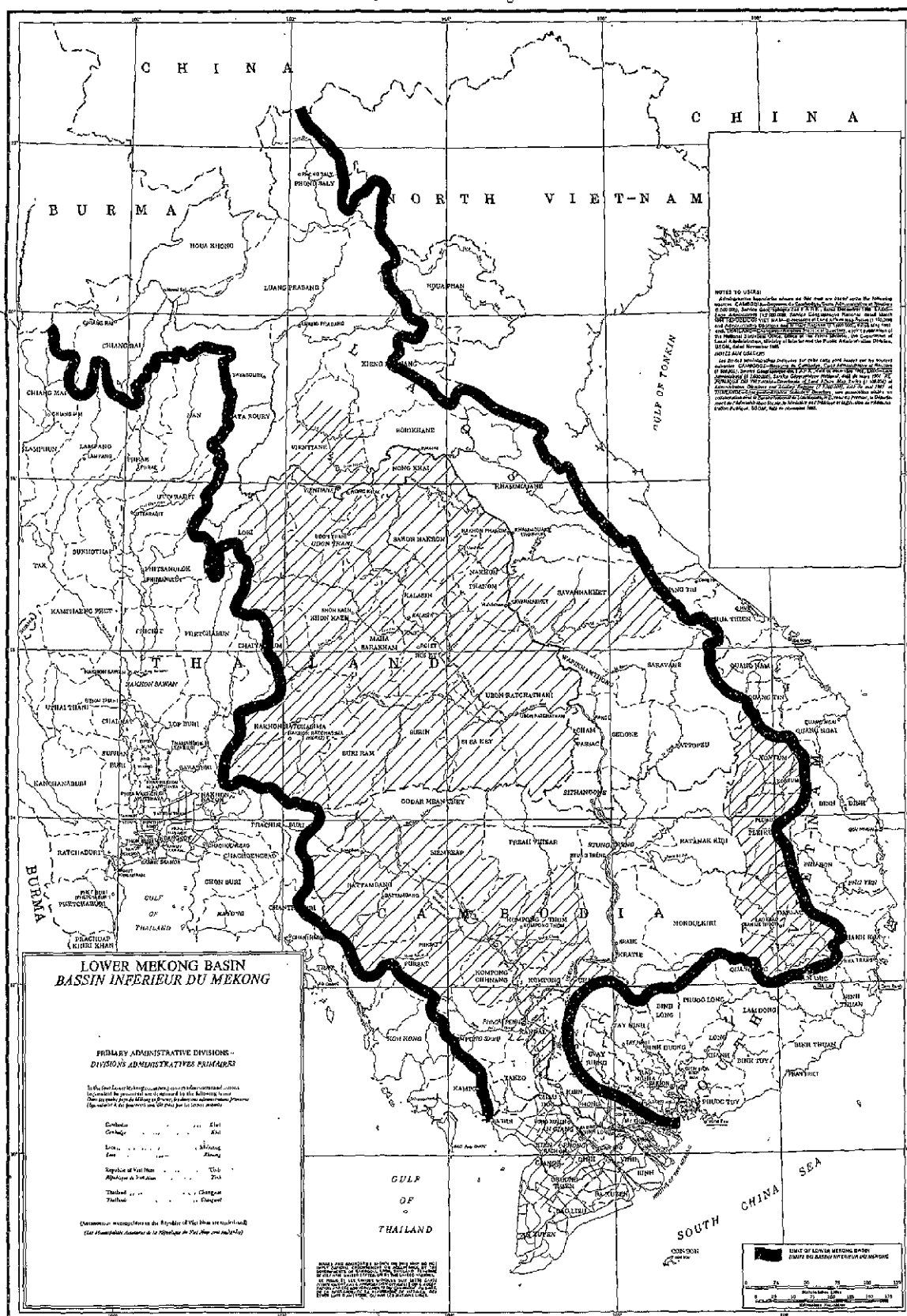
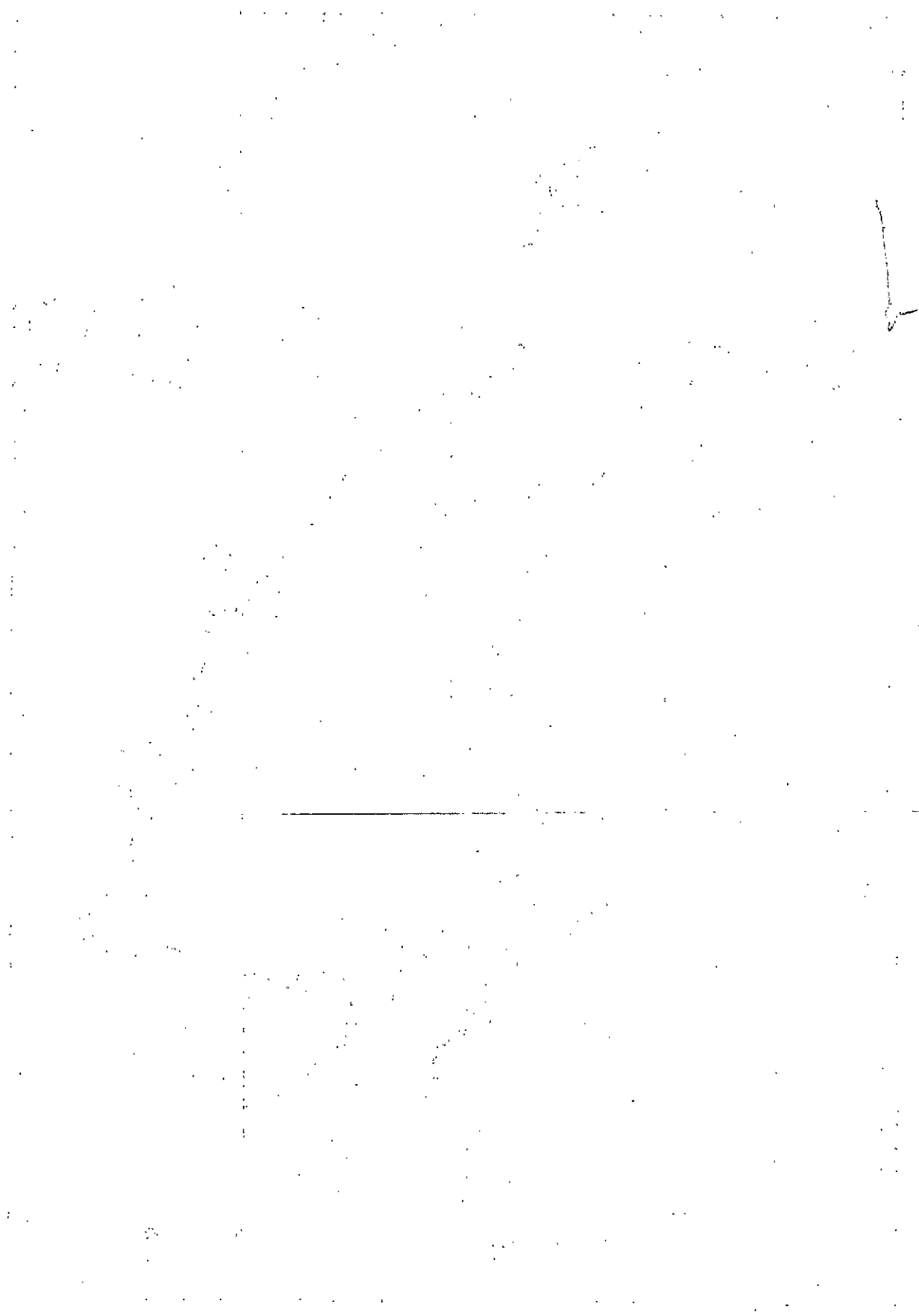


Plate II. 1.



2. Cambodia

A brief summary of the history of kenaf production in Cambodia published in 1971 by the Agronomy Division of the Directorate of Agriculture indicates that kenaf was first planted at Prek Leap in 1953/1954 from seed imported from French Equatorial Africa and, in 1958/1959, at the National Agricultural College at Chamcar Mon, (Phnom-Penh) from seed supplied by the U.S. Operations Mission. As a result of the excellent trial results obtained, it was widely distributed to the farmers in 1967 and, by 1971, occupied more than 80 percent of the total jute/kenaf planting area in the Provinces of Battambang, Siemreap, Pursat, Kompong Chang, Kompong Cham, Kompong Thom, and Kandal, mainly due to the fact that the kenaf outyielded jute and was more drought and disease resistant (see Plate II.3.).

The Agronomy Division report states that, depending upon the variety's photo-sensitivity, two kenaf crops per year can be planted, i.e. one rainy season crop from May to September/October and one dry season crop from February to June/July.

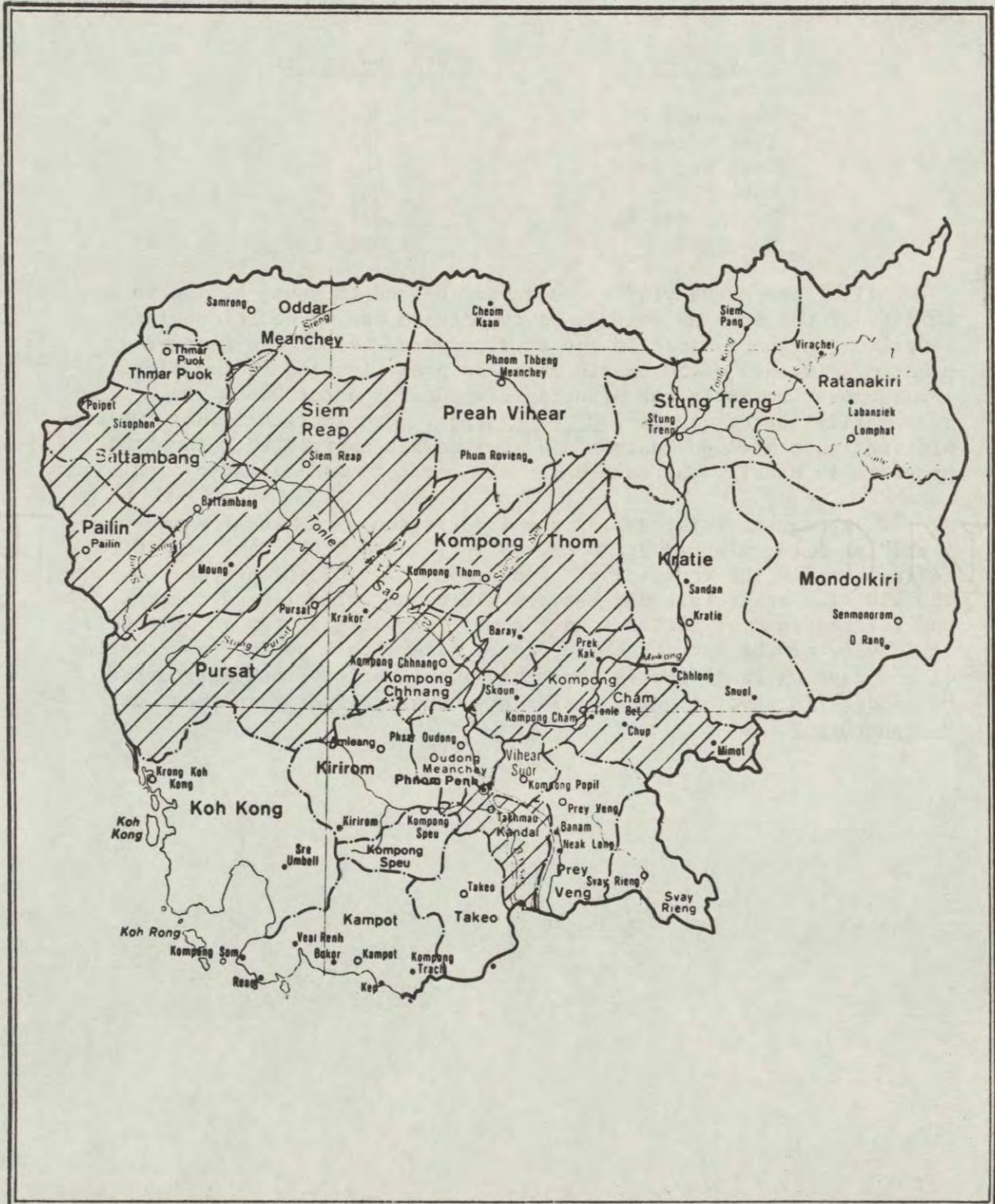
Some research trials were carried out, under Mekong Committee auspices, with jute and kenaf at the Banam (near Battambang) and Prek Thnot Experiment Stations as recently as the 1971/1972 season. The trials concerned jute and kenaf seed production at Banam and kenaf variety testing at Prek Thnot.

Only a summary of the results obtained at Banam could be located. This indicates that the best seed yields were achieved with the Bronca Brazil, Toxa Brazil and Solimoes varieties of jute and with the local variety of kenaf.

The kenaf variety trials at Prek Thnot included two H. sabdariffa varieties (Thai Red Stem and Thai Green Stem) and four H. cannabinus varieties (Cuba 108, Cuba 2032, Guatemala 4, and Everglades 71). The trials were planted on acid paddy soils on May 22 in rows 50 cm. (20 in.) apart and at 8 cm. (3 in.) distance between the plants in the row, fertilized at the rate of 120-60-30 kg. of N-P₂O-K₂O per hectare, weeded three times and irrigated three times; the stalks were



Kenaf Producing Provinces, Cambodia, 1971



harvested at the flowering stage and the following retted fiber yields were obtained:

<u>Variety</u>	<u>Yield (kg./ha.)</u>
Guatemala 4	565
Thai Green Stem	691
Thai Red Stem	743
Cuba 2032	962
Everglades 71	1,031
Cuba 108	1,325

All of the above yields are quite low and this may be due to the acidity of the soil as well as to inundation due to deficient land levelling, as emphasized in the trial report. Also, the inter-row planting distance of 50 cm. is much too great leading to low plant populations; an inter-row planting distance of about 20 cm. is customarily being used for H. cannabinus. The fact that Cuba 108 significantly outyielded Guatemala 4 is somewhat unexpected, since the opposite is usually the case under similar soil and climatic conditions.

A subsequent trial during the 1973 season with "local variety kenaf" at Banam planted at 20 cm. (8 in.) between the rows and 10 cm. (4 in.) within the rows (plant population = 500,000 plants/ha.; 200,000 plants/acre) yielded between 1.2 tons (unfertilized control) and 2.7 tons/ha. of retted fiber, a most encouraging result particularly in view of the fact that the report refers to a period to flowering of 156 days which indicates that the "local variety" belongs to the H. sabdariffa species whose yields are usually lower than those of H. cannabinus.

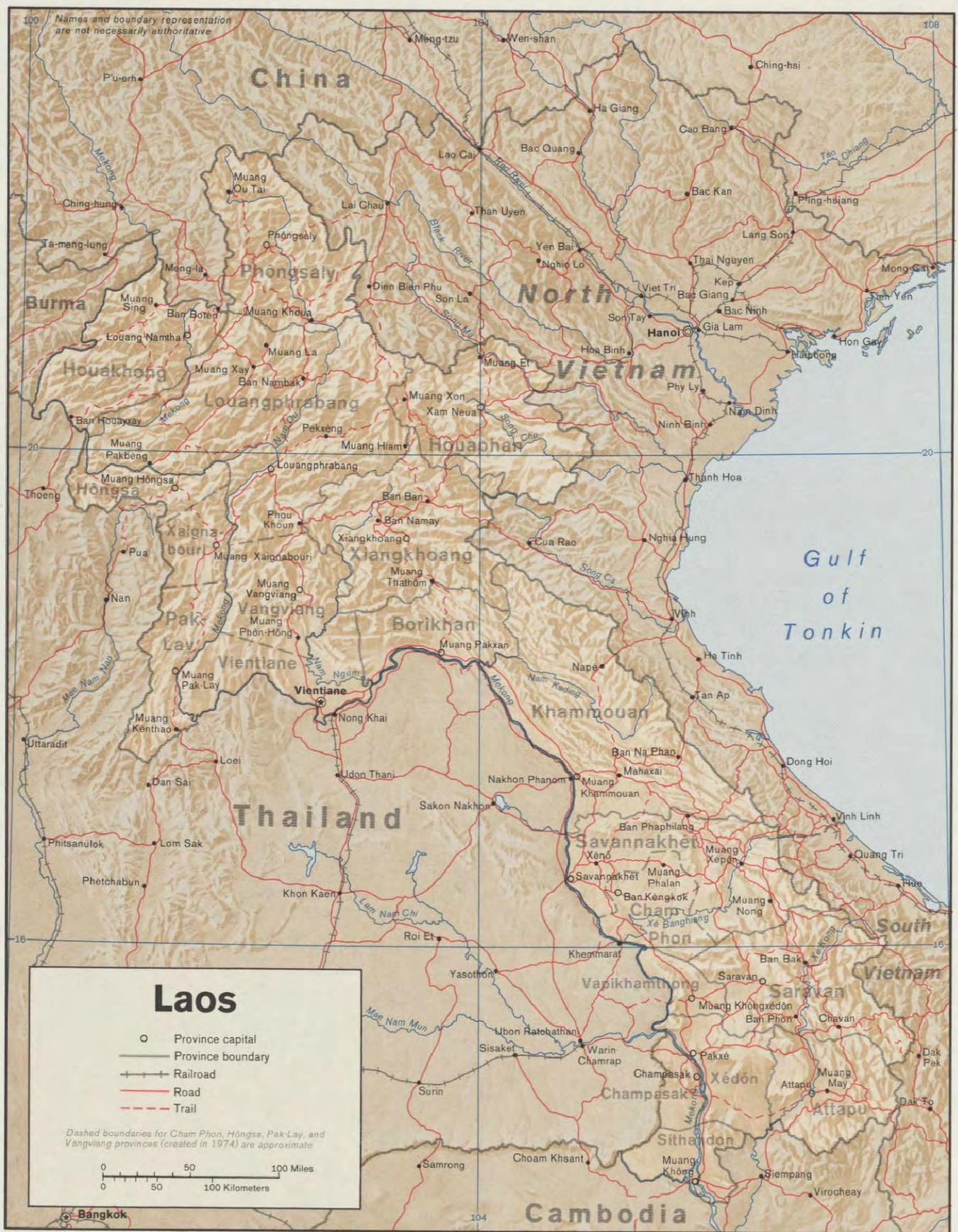
3. Laos

No sustained attempts have been made in the past to develop a kenaf industry in Laos. Local demand for bags, hessian and other jute, kenaf and allied fiber based finished goods is very limited and would not justify the establishment of an economic size industrial plant. Furthermore, such limited demand could always easily and conveniently be met by imports from the large kenaf industry in neighboring Northeast Thailand. Nevertheless, some efforts were made to develop a native fiber plant, locally known as "Polompom", into a commercial bagging raw material source.

Polompom is a prolific and abundant bast fiber indigenous to Laos. It grows extensively north of Vientiane in the Nam Ngum Valley, as well as in the area of Savannakhet and Tchepone (see Plate II.1.). Polompom is a woody, hibiscus-like perennial, and is a potential substitute for jute and kenaf. However, spinning trials carried out in France have indicated that the retted fiber, although suitable for bag manufacture, is not of as good a quality as jute or kenaf.

In 1933/1934, a small bag factory was installed in Vientiane to utilize native stands of polompom located in the Nam Ngum Valley. The project was not successful, principally because the wild plants varied in age, and a uniformly retted fiber could not be produced. In 1960, another company acquired a long-term concession for some 40,000 hectares of land north of Vientiane, with the thought of utilizing native stands of polompom. The war curtailed this effort and the project lapsed, although the promoters were still anxious to revive it some ten years later.

In order to check on the possibilities of using polompom for a then once more proposed bag factory project, the village of Sendin on the Nam Ngum River in the Nakham area (some 40 kms. north of Vientiane) was visited by the Consultants in 1965 under a Small Industry Development assignment of theirs to Laos at the time. The village was said to lie in the densest polompom area in the country. However, the visit was disappointing. The 6 to 7 km. access road from the main Vientiane-Luang Prabang highway was, in part, almost impassable even by jeep, although the visit took place at the end of the dry season. It would obviously become quite impassable as soon as the rains start, and would probably remain so until several months after the end of the rainy season.



Only a few very poor and scattered stands of polompom were located, although the ex-foreman of the French company was used as a guide. It was claimed that the stands used to be very dense at one time but, since their abandonment, they were overgrown by trees and bushes. As soon as the land was cleared (by cutting, bulldozing and burning), the polompom would re-establish itself and become as dense as before. Nevertheless, a small area which had been kept cleared over the years showed only scattered clumps of polompom.

Each clump contained a considerable number of individual stalks, but of many different ages. This difference in age among the stalks would, undoubtedly, lead to renewed problems in processing and the production of uniform fiber (both with regard to strength and fineness).

Discussions with the ex-foreman and several former workmen (who still produce small quantities of fiber for their own use) disclosed that one man could collect and process some 6 to 8 kg. of semi-retted bast ribbon daily. There would probably be an additional 20 percent weight loss in transforming such ribbon into completely retted fiber for bag manufacture in a central retting installation. Accordingly, a fiber requirement of, say, 2,500 tons yearly for a minimum economic size bag factory would be equivalent to some 3,100 tons of semi-retted ribbon. On the basis of a 25-day working month and a six-month harvesting season, one man could produce ($6 \times 25 \times 6 = 900$ kg.) 0.9 tons of ribbon. Hence, $(3,100/0.9)$ 3,400 men would be required to harvest the necessary quantity of ribbon for the bag mill. This is an obvious impossibility, in view of the chronic labor shortage in Laos.

It was, therefore, recommended at the time that a bag industry in Laos should be based on the use of kenaf, cultivated specifically for the purpose. Once a bag mill existed, trials could then be made with the blending of polompom with kenaf in order to develop a source of income for those villages that can produce polompom ribbon. Mechanization of polompom harvesting or decorticating would not be feasible, unless special plantations were established. However, it would then be much preferable to establish plantations of kenaf, for which a great deal of experience already exists, which can easily be mechanized, and whose yields, quality and production costs are known.

Experimentation with kenaf (H. sabdariffa and/or H. cannabinus) in Laos has been extremely limited. As far as could be established, varietal test plots were planted at two nurseries near Vientiane in 1958, but no records of the test results could be obtained. Oral statements indicate that the plants grew well and attained a height of some 4 meters. Similar results are said to have been obtained with scattered and inadequately supervised test plantings near Savannakhet. Based upon experience in neighboring Cambodia and Thailand, there is of course no reason why economically attractive yields of both kenaf species should not be obtained in Laos under the proper conditions.

4. Viet-Nam

4.1. Kenaf

Although kenaf has long been traditionally produced by numerous farmers in Viet-Nam* for their own and for village consumption, organized kenaf production is believed to date back only some 20 years. Following the introduction of both H. cannabinus and H. sabdariffa seed and the completion of successful nursery trials, the first commercial plantings were made in 1958. At that time, six tons of South Asian kenaf seed was imported from Thailand by the U.S. Technical Assistance Program and distributed to settlers in Pleiku Province and farmers elsewhere in the country; at the same time, the then only jute mill, whose parent company also owned several tea, coffee and rubber plantations, purchased another six tons of similar seed from Thailand. A total of 337 hectares of kenaf were planted in 1958, some 300 hectares in Pleiku and Tuyen-Duc Provinces, 20 hectares in Phuoc Tuy Province, and various small areas in Long Khanh and Tay Ninh Provinces. Approximately 180 tons of retted fiber was produced, all of which was used by the local jute mill.

Table II.1. shows the annual kenaf fiber planting areas and production since 1958. The incompleteness of the table is due to the fact that recent records are presently inaccessible to the Consultants. By 1961, kenaf was being produced in 15 provinces including Vinh Long, Tay Ninh, Bin Duong, Binh Long, Bien Hoa, Phuoc Tuy, Long Khanh, Phuoc Thanh, Phuoc Long, Quang Duc, Tuyen Duc, Darlac, Pleiku, Kontum, and Thua Thien (see Plate II.6.).

The decline in kenaf plantings by almost 50 percent in 1962 was due principally to the lack of fertilizer and credit loans and increasing lack of security in many of the villages located adjacent to the Cambodian and Laotian borders. At that time, local fiber demand amounted to some 10,000 tons annually, including 6,000 tons for

* In this Study, the term Viet-Nam designates South Viet-Nam, i.e. the area up to the 17th parallel; although the Consultants are aware of the existence of a fair size kenaf industry in North Viet-Nam, detailed information on that industry is presently not accessible to them.



Table II.1.

Kenaf Fiber Production, Viet-Nam
1958 to 1975

Year	Planting Area (Ha.)	Production (Tons)
1958	337	180
1959	2,062	1,650
1960	3,689	3,000
1961	9,050	9,000
1962	4,150	3,245
1963	n.a.	n.a.
1964	n.a.	n.a.
1965	n.a.	n.a.
1966	n.a.	n.a.
1967	n.a.	n.a.
1968	n.a.	n.a.
1969	n.a.	n.a.
1970*	5	5
1971*	20	20
1972*	400	400
1973*	800	820
1974*	1,600	1,680
1975*	4,000	4,250

Note: *5-Year Rural Economic Development Plan, 1971-1975,
Estimates and Projections.

the Societe Vietnamienne du Jute and 3,000 tons for the Donai Textiles Company mill then under construction.

In Viet-Nam, the peasant farmers plant the kenaf in rows using a spacing of roughly 20 x 5 cm. or the equivalent of about 25 kg. of seed per hectare for H. cannabinus and 18 kg. for H. sabdariffa. The usual planting method by hand is to open shallow rows 20 cm. apart to a depth of about 3 cm. using a homemade rake having from four to six coarse teeth. Fertilizer is then spread evenly in the rows by hand and the rake is again drawn through the rows to mix the fertilizer with the soil. Next the seed is dropped into the rows by hand, spacing it about 5 cm. apart as single or double seeds. It is then covered by soil to a depth of about 1 cm. by turning the rake upside down and pulling it over the rows. This planting procedure, including row opening, fertilization and covering, takes about ten man-days of labor per hectare.

A second method of planting favored by some farmers is first to apply fertilizer in rows using a single row, hand-pushed fertilizer drill, followed by planting in the same row with a single row, hand-pushed seed drill. This procedure requires about five man-days per hectare. If the seed is treated with a fungicide, which was considered necessary in Viet-Nam to combat soil borne fungus diseases, the mechanical planting method was recommended, especially if the more toxic mercurial fungicides are used.

Intensive nursery research trials were carried out in Viet-Nam during the 1957 to 1962 period, on both the H. cannabinus and H. sabdariffa species, and improved seed was produced on a sizeable scale for distribution to the peasant farmers. Condensed results of the most important trials are shown in Tables II.2., II.3. and II.4., and the following overall conclusion are reached:

- (i) Kenaf can readily be grown in Viet-Nam;
- (ii) Amongst the H. sabdariffa varieties, Indonesian THS-22 and THS-24 produced outstanding yields and did not lose their nematode resistance; Thai Red kenaf produced the highest yield on new soils, but became nematode susceptible after being planted for several years in Viet-Nam;
- (iii) Recommended fertilization for H. sabdariffa is 60-30-120 as kilograms of N-P₂O₅-K₂O per hectare, especially in the Central Highlands;

Table II.2.

H. Sabdariffa Variety Trial, Viet-Nam

Location - Eakmat Nursery

Planting Date - May 2 Plot Size - 5 x 5 m.
Harvesting Date - October 26 Plant Spacing - 20 x 4 cm.
Fertilization 60-30-60 Kg./Ha. of N-P₂O₅-K₂O

Variety	Plant Height at Harvest (m.)	Retted Fiber Yield (Kg./Ha.)
THS-2	3.40	3,460
THS-8	3.47	2,335
THS-12	3.59	2,910
THS-17	3.42	2,690
THS-22	3.45	4,265
THS-24	3.59	3,980
THS-30	3.58	3,890
THS-35	3.65	2,620
THS-44	3.58	3,450
THS-53	3.48	3,460
Thai Red	3.27	2,890

Table II.3.

H. Sabdariffa Fertilizer Trial, Viet-Nam

Location - Eakmat Nursery

Planting Date	- May 7	Fertilization:	N ₁ - 60 kg. N/ha.
Harvesting Date	- October 29		N ₂ - 120 kg. N/ha.
Plot Size	- 10 x 10 m.		P ₁ - 30 kg. P ₂ O ₅ /ha.
Plant Spacing	- 20 x 5 cm.		P ₂ - 60 kg. P ₂ O ₅ /ha.
Variety	- Thai Red		K ₁ - 60 kg. K ₂ O/ha.
			K ₂ - 120 kg. K ₂ O/ha.

Fertilizer	Plant Height at Harvest (m.)	Retted Fiber Yield (Kg./Ha.)
0	2.4	610
N ₁	2.3	460
N ₂	2.5	225
P ₁	2.4	590
P ₂	2.2	270
K ₁	2.7	1,385
K ₂	2.4	1,080
N ₁ P ₁	2.2	480
N ₂ P ₂	2.4	560
N ₁ K ₁	2.2	890
N ₂ K ₂	2.3	1,035
P ₁ K ₁	2.4	1,365
P ₂ K ₂	2.7	1,660
N ₁ P ₁ K ₁	2.5	1,515
N ₁ P ₁ K ₂	2.9	2,630
N ₂ P ₂ K ₂	2.6	1,700

Table II.4.

H. Cannabis Variety Trial, Viet-Nam

Location - Hung Loc Nursery

Plot Size = 100 sq.m. Plant Spacing = 20 x 10 cm.

Fertilization = 0-30-60 as Kilograms of N-P₂O₅-K₂O/Ha.

Variety	Planting Date	Height at Flowering (m.)	Retted Fiber Yield (Kg./Ha.)
<u>Photo-Sensitive Varieties</u>			
2A	May 2	3.9	2,063
Everglades 41	May 9	3.2	1,575
Everglades 71	May 2	3.3	2,352
<u>Photo-Insensitive Varieties</u>			
18B	May 25	3.6	1,162
20A	May 24	3.5	1,334
28A	May 5	3.7	1,463
38F	May 26	3.0	1,722

- (iv) Amongst the H. cannabinus varieties, the best yields were obtained from the Everglades 71 (photo-sensitive) and Guatemala 38F (photo-insensitive) varieties;
- (v) Recommended fertilization for H. cannabinus is either 60-30-60 or 60-30-120 as kilograms of N-P₂O₅-K₂O per hectare;
- (vi) Kenaf variety trials on heavy clay showed good yields; but they were inferior to those obtained from the better jute varieties;
- (vii) The optimum planting date for the photo-sensitive H. cannabinus varieties is May 15 with yields gradually declining with the later plantings;
- (viii) Good rotation crops for kenaf in Viet-Nam are groundnuts, paddy and mung beans.

Surprisingly, the tables show lower average fiber yields for H. cannabinus than for H. sabdariffa whereas the opposite is normally true in other kenaf producing areas. This may be due to the choice of test sites and, particularly, the strong nematode incidence at these sites which would substantially reduce the H. cannabinus yields. Furthermore, the photo-insensitive H. cannabinus varieties normally outyield the photo-sensitive ones; again the tables indicate the opposite. However, excellent H. sabdariffa yields appear to have been obtained in the trials under discussion, in fact substantially higher yields than normally obtained elsewhere even under irrigation.

There is no question that further intensive trials will have to be carried out in Viet-Nam prior to the implementation of a large-scale kenaf for paper pulp production program. However, there is also no doubt that kenaf can be grown successfully in the country.

4.2. Jute

Although some jute had been planted for many years in South Viet-Nam, it was not until the Japanese occupation from 1942 to 1945 that the crop was grown in any volume. Table II.5. shows the available data on jute planting areas and fiber production from 1941 onwards. After the occupation, jute culture in South Viet-Nam was practically abandoned and the only production was in the form of scraped ribbons used locally for twine, cordage, hammocks, and mat backings.

In 1957, South Viet-Nam initiated a five-year jute research and production program. A jute experiment station was established at My-Thoi in An-Giang Province, some 19 tons of local variety jute seed were purchased for distribution to farmers in 1958, arrangements were made to establish agricultural loans to jute growers, instruction booklets on jute production were printed and distributed, and a minimum price for retted jute fiber was established. The 706 ha. of jute planted in 1958 produced 970 tons of scraped ribbon; since the market price of ribbon exceeded the established minimum price for retted fiber, very little such fiber was produced.

The jute area was further increased in 1959 and 1960, but due to poor security and a damaging flood only 1,410 ha. of jute were harvested in 1961 producing 1,347 metric tons of which about 250 tons was retted fiber which was sold to the local jute mill. The 1962 planting area amounted to an estimated 1,620 ha. which produced 2,035 tons and thus a substantially higher output per unit area than previously, and that due to the fact that almost the entire area was planted with new high yielding varieties.

As in the case of kenaf, intensive research trials were carried out in Viet-Nam on jute from 1957 onwards. New varieties were introduced from India, China, Japan, Thailand, Cambodia and Brazil, and improved seed was multiplied for distribution to farmers. The My-Thoi jute nursery comprised 4 ha. of heavy clay soil subject to flooding for about two months every fall at the height of the rainy season.

Table II.5.

Jute Fiber Production, Viet-Nam
1941 to 1975

Year	Planting Area (Ha.)	Production (Tons) (1)
1941	131	n.a.
1942	343	220
1943	1,175	n.a.
1944	2,896	1,800
.	.	.
.	.	.
.	.	.
1957	120	120
1958	706	970
1959	1,250	1,805
1960	1,800	2,420
1961	1,410	1,347
1962	1,620	2,035
.	.	.
.	.	.
.	.	.
1970 ⁽²⁾	450	450
1971 ⁽²⁾	450	450
1972 ⁽²⁾	550	550
1973 ⁽²⁾	650	680
1974 ⁽²⁾	750	810
1975 ⁽²⁾	825	940

Notes: (1) Mostly hand scraped ribbon; only a small percentage of retted fiber production.

(2) 5-Year Rural Economic Development Plan, 1971-1975, Estimates and Projections.

The Brazilian Rofa, Branca and Lisa and the South Asian Halmaheira varieties produced the best yields. Again, the test results are condensed in Tables II.6. and II.7. Table II.8. shows the results of a 1960 trial with all introduced varieties; although it indicates seed rather than fiber yields, it does include the names and origins of the introduced varieties, the days to flowering, and the stalk height at maturity.

Again and as for kenaf, the trial results summarized in the tables are by no means conclusive.

As shown in Plate II.6., in 1961 jute was grown in four provinces in Viet-Nam, namely Kien Giang, An Giang, Kien Phong and Vinh Long, all in the Delta.

Table II.6.

Jute Variety Trial, Viet-Nam

Location - My Thoi Nursery

Planting Date - May 25 Plot size - 10 x 10 m.
Harvesting Date - Sept. 20 to Oct. 4 Plant spacing - 30 x 5 cm.
Fertilization - 60-20-60 as kilograms of N-P₂O₅-K₂O/ha.

Variety	Retted Fiber Yield (Kg./Ha.)
Lisa	2,350
Rofa	2,300
Branca	2,000
Halmaheira	1,900
Local	1,700

Jute Fertilizer Trial, Viet-Nam

Table II.7.

Location - My Thoi Nursery

Planting Date - May 15 Fertilizations:
 Plot Size - 10 x 10 m. N₁, N₂, N₃ - 30, 60, 90 kg. N/ha.
 Seeding Rate - 5 kg./ha. P₁, P₂, P₃ - 15, 30, 45 kg. P₂O₅/ha.
 Final Plant Spacing - 30 x 5 cm. K₁, K₂, K₃ - 30, 60, 90 kg. K₂O/ha.

Variety	Halmaheira	Rofa	Branca	Lisa
Fertilizer	Retted Fiber Yield (Kg./Ha.)			
N ₁	1,200	1,200	1,400	1,650
N ₂	1,450	1,700	1,800	1,750
N ₃	2,000	2,150	2,400	1,600
P ₁	1,600	550	900	600
P ₂	350	650	1,200	800
P ₃	650	950	1,000	550
K ₁	1,900	500	900	700
K ₂	350	850	750	700
K ₃	700	800	1,300	600
N ₁ P ₁	1,750	1,750	1,500	1,450
N ₂ P ₂	2,200	1,900	1,800	2,150
N ₃ P ₃	2,200	2,500	1,900	2,150
N ₁ K ₁	2,300	1,750	500	2,200
N ₂ K ₂	2,000	2,200	1,850	1,650
N ₃ K ₃	2,200	2,500	1,900	2,150
P ₁ K ₁	2,600	1,200	1,300	1,100
P ₂ K ₂	1,900	1,100	1,300	900
P ₃ K ₃	1,100	1,000	1,100	1,100

Note: Subsequent trials apparently showed that a N₂P₁K₂ fertilizer application further increases fiber yields.

Jute Variety Trial, Viet-Nam

Location - My Thoi Nursery

Planting Date	- May 10	Fertilization.
Plot Size	- 10 x 10 m.	Pre-Treatment - 8 Tons Manure/Ha.
Seeding Rate	- 5 Kg./Ha.	40-60-15 as Kilograms of
Final Plant Spacing	- 30 x 30 cm.	N-P ₂ O ₅ -K ₂ O/Ha.

Rank	Variety	Origin	Days to Flower	Height at Maturity (m.)	Seed Yield (Kg./Ha.)
1	Halmahera	Taiwan	111	2.10	450
2	Rofa	Brazil	153	2.60	250
3	Lisa	Brazil	153	2.40	300
4	Branca	Brazil	162	2.60	250
5	Lardyai	Thailand	134	2.50	800
6	Ayuthia	Thailand	134	2.20	750
7	Cambodia	Cambodia	145	2.10	700
8	Nonravaeng	Thailand	134	2.10	850
9	Hargola	Thailand	134	2.10	700
10	Chinsura Green*	Philippines	132	2.10	950
11	Local	Viet-Nam	142	2.00	600
12	JRO-632*	India	59	2.00	200
13	Pitsanuloke	Thailand	113	2.00	700
14	Mukdaharn	Thailand	80	1.90	80
15	D-154	India	101	1.80	500
16	Olitorius*	India	59	1.80	150
17	Shui-Shang	Taiwan	70	1.80	150
18	India	India	101	1.80	350
19	Huwei	Taiwan	70	1.70	150
20	Sinfon	Taiwan	80	1.70	650
21	Solimoes	Brazil	132	1.70	500
22	Taichung	Taiwan	70	1.70	100
23	JRO-753*	India	59	1.70	50
24	Mookhadarn	Thailand	91	1.70	300
25	Syhi	Japan	91	1.70	200
26	Sukothai	Thailand	80	1.60	400
27	Naung-Tow	Thailand	91	1.60	350
28	Philippine*	Philippines	59	1.60	450
29	Taiwan Red	Taiwan	59	1.50	350
30	Kenaf**	Thailand	163	3.00	400

Notes: *C. olitorius

**Hibiscus sabdariffa var. altissima. All others C. capsularis.

Table II.8.

5. Thailand

5.1. History of the Thai Kenaf Fiber Industry

Commercial kenaf fiber production in Thailand first started in 1950 when some 5,000 ha. (31,000 rai) were planted to this crop. Production increased rapidly from 1956 onwards and reached a high point in 1966 with a planting area of 528,000 ha. (3.3 million rai) and an output of 622,000 tons and a second such peak level in 1973, when 544,000 ha. (3.4 million rai) were planted to kenaf and an output of 625,000 tons was achieved. In other years, kenaf planting areas and production have fluctuated widely but, with the exception of 1968 (176,000 ha./1.1 million rai, 184,000 tons), have varied generally between 320,000 ha. and 480,000 ha. (2 and 3 million rai) planting area and 350,000 and 500,000 tons output during the last decade, with a general average of some 384,000 ha. (2.4 million rai) and 440,000 tons annually. For the last 15 years, kenaf has consistently maintained its position amongst the seven most important exports of Thailand and, between 1965 and 1973, has contributed from 6 to 15 percent to the country's annual foreign exchange earnings from those principle exports (Tables II.9. and II.10.).

Practically all of the kenaf in Thailand is grown in the fifteen - now sixteen - Changwats (Provinces) of the Northeast (Plates II.8. and II.9.), one of the lowest income areas of the country and where kenaf has long been the single most important - and often the only - cash crop, although tapioca production has recently been expanding in the region. The monetary value of the rice crop exceeds that of kenaf, but rice is produced in the Northeast mainly for family consumption and thus does not contribute significantly to cash income. Also, kenaf is grown on generally poor upland soils unsuitable for rice cultivation and on which few crops can be produced profitably (again except recently tapioca) but which, nevertheless, return economically attractive yields of kenaf fiber. On the assumption of an average annual crop of 440,000 tons of retted kenaf fiber, an average fiber yield of 1,150 kg. per hectare (184 kg. per rai), a \$2.50/kg. (US\$0.125/kg.) farm price for "Mixed Grade" fiber, and an average planting area of 1.6 hectares (10 rai) per farm family, the cash income to the growers amounts to some \$1,100 million (US\$55 million) per year shared by approximately 250,000 farm families. In addition, kenaf production generates work and income for numerous shopkeepers, kenaf traders and transport workers



Total Quantity and Value of the Principal Exports, Thailand
1960 to 1974

Year	Rice		Rubber		Tin		Maize		Sugar		Tapioca Products		Kenaf & Jute	
	Metric Tons	Million ฿	Metric Tons	Million ฿	Metric Tons	Million ฿	Metric Tons	Million ฿	Metric Tons	Million ฿	Metric Tons	Million ฿	Metric Tons	Million ฿
1960	1,202,772	2,570	169,655	2,579	17,114	537	514,745	551	5,723	8	269,733	288	61,796	230
1961	1,575,998	3,598	184,598	2,130	18,104	617	567,236	597	1,537	3	443,376	446	143,477	626
1962	1,271,623	3,240	194,280	2,111	19,841	685	472,405	502	43,019	46	400,788	423	237,898	579
1963	1,417,673	3,424	186,887	1,903	22,003	741	744,046	828	52,823	122	427,443	439	125,753	358
1964	1,896,258	4,389	226,993	2,060	22,339	962	1,115,041	1,346	48,908	211	738,859	653	162,095	495
1965	1,895,223	4,334	210,854	1,999	20,503	1,166	804,380	969	83,834	100	719,442	676	316,989	1,102
1966	1,507,550	4,001	202,535	1,861	18,898	1,316	1,218,537	1,520	54,858	82	688,603	644	473,269	1,614
1967	1,482,272	4,653	211,118	1,574	27,107	1,822	1,090,762	1,355	15,013	37	781,357	726	317,112	866
1968	1,068,185	3,775	252,220	1,816	24,017	1,510	1,480,841	1,556	52	-	888,854	772	289,478	674
1969	1,023,044	2,945	276,381	2,664	23,431	1,631	1,476,106	1,674	16,102	47	957,091	876	255,978	780
1970	1,063,064	2,516	275,610	2,232	22,246	1,618	1,371,474	1,857	56,248	94	1,326,865	1,223	257,663	719
1971	1,661,840	2,901	307,873	1,901	21,703	1,561	1,829,878	2,251	174,571	382	1,112,466	1,229	270,977	933
1972	2,112,114	4,437	317,695	1,862	21,840	1,664	1,843,619	2,085	407,501	1,264	1,311,038	1,547	255,093	1,087
1973	847,870	3,601	405,450	4,754	21,647	1,989	1,394,643	2,936	254,208	1,067	1,813,099	2,506	263,850	1,052
1974	931,402	8,919	355,278	4,999	20,291	3,010	1,595,162	4,513	436,113	3,677	251,600	768	218,974	788

Source: Department of Customs

Note: Baht (฿) 20.00 = US\$1.00

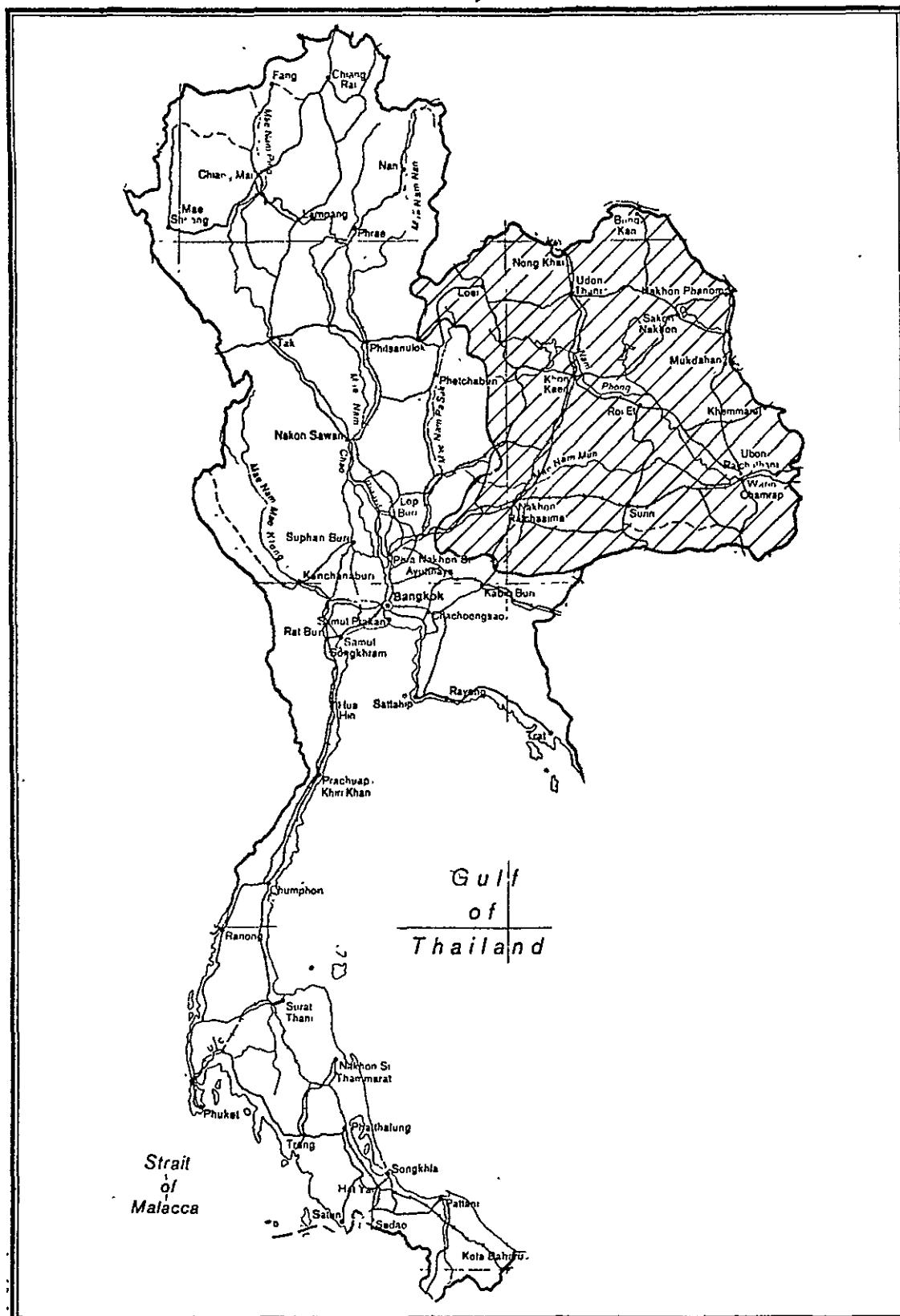
Export Value of Kenaf & Jute in Relation to the
Principal Exports, Thailand, 1960 to 1974

Year	Export Value Rating, Kenaf No.	Total Export Value 7 Principal Exports (.)	Export Value Kenaf Million Baht	%age of Total Export Value, Kenaf (.)
1960	6	6,763	230	3.40
1961	3	8,017	626	7.81
1962	6	7,586	579	7.63
1963	6	7,815	358	4.58
1964	6	10,116	495	4.89
1965	4	10,364	1,102	10.63
1966	3	11,038	1,614	14.62
1967	5	11,033	866	7.85
1968	5	10,103	674	6.67
1969	6	10,617	780	7.35
1970	6	10,359	719	6.94
1971	6	11,148	933	8.37
1972	7	13,982	1,087	7.77
1973	7	17,905	1,052	5.86
1974	6	26,674	788	2.95

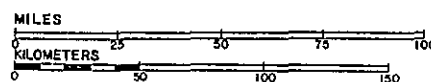
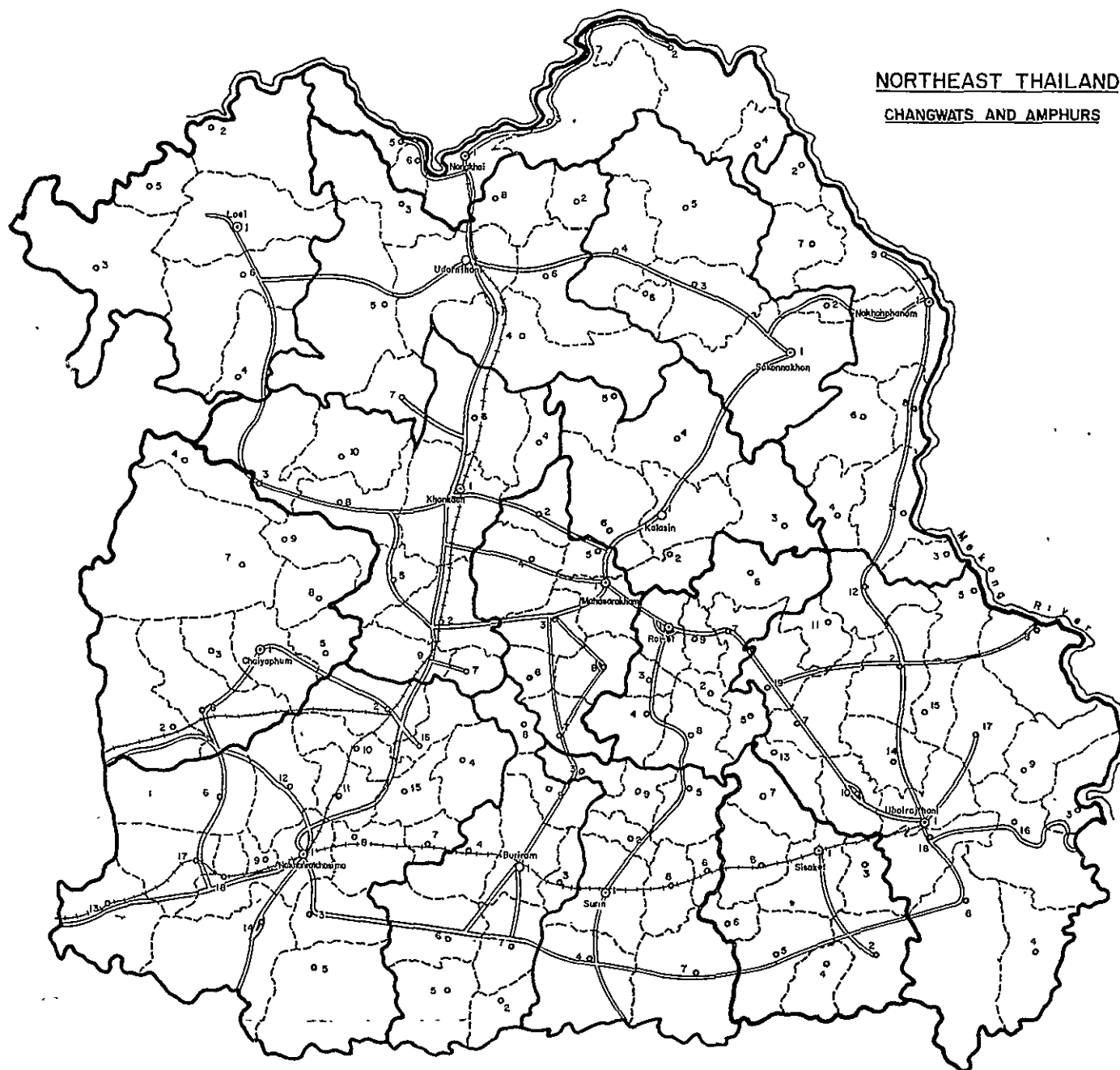
Note: Baht 20.00 = US\$1.00

Table II.10.

Kenaf Production Area, Northeast Thailand



NORTHEAST THAILAND
CHANGWATS AND AMPHURS



— HIGHWAY
 +---+ RAILROAD

Plate II. 9. (A)

Plate II.9.(B)

Northeast Thailand
Changwat and Amphurs

- | | | | |
|-----------------------------------|---------------------------------------|------------------------------------|-------------------------------------|
| 1. <u>BURIRAH</u> ⁺ | 1. <u>MAHASARAKHAM</u> ⁺ | 1. <u>ROIET</u> ⁺ | 1. <u>UBOLRAJTHANI</u> ⁺ |
| 2. Bang Krat | 2. Borabu | 2. Artsarwart | 2. Annardcharoen |
| 3. Kasang | 3. Chiang Yun | 3. Chaturaphican | 3. Bandon* |
| 4. Lam Flai Mat | 4. Kosumpisai | 4. Kasetivisai | 4. Boodarik |
| 5. Iani Sai* | 5. Kuntharawichai | 5. Phanom Prai | 5. Chanuman |
| 6. Nong Rong | 6. Nachuak* | 6. Pon Tong | 6. Dejudom |
| 7. Prakhon Chai | 7. Phayakaphumtisai | 7. Selaphum | 7. Kamnuankaew |
| 8. Puttaisong | 8. Wapipathum | 8. Sunanphum | 8. Khemarat |
| 9. Sa Tuk | | 9. Tawatburi | 9. Khoangjian |
| | | | 10. Khuangnai |
| 1. <u>CHAIYAPHUM</u> ⁺ | 1. <u>NAKON PHANOM</u> ⁺ | 1. <u>SAKONNAKHON</u> ⁺ | 11. Kutchun* |
| 2. Banmetnarong | 2. Ban Phaeng | 2. Ban Kusuman* | 12. Lerngnokthar |
| 3. Bankawan | 3. Don Tan* | 3. Phannanikhon | 13. Mahachanachai |
| 4. Cornsarn | 4. Kham Chai* | 4. Swang Daen Din | 14. Muangsamsip |
| 5. Corneawan | 5. Mukdahan | 5. Wanoniwat | 15. Pana |
| 6. Juturas | 6. Nakae | 6. Waritchaphum | 16. Phibulmangshan |
| 7. Kasetsoomboon | 7. Sisongkhram | | 17. Trakanphuephol |
| 8. Kengkror | 8. That Phanom | 1. <u>SISAKET</u> ⁺ | 18. Warichamrarb |
| 9. Pukiew | 9. Thanthen | 2. Kantaralak | 19. Yasothon |
| | | 3. Kantararon | |
| 1. <u>KALASIN</u> ⁺ | 1. <u>NAKHONRACHSIMA</u> ⁺ | 4. Kunhan | + MIANG AMPHUR |
| 2. Kamalasai | 2. Buayai | 5. Kukhun | * KING AMPHUR |
| 3. Kuchinrai | 3. Chokchai | 6. Prangku* | |
| 4. Sahat Sakhan | 4. Chumpoung | 7. Rari Salai | |
| 5. Thakun To* | 5. Cornburi | 8. Utumponphisai | |
| 6. Yang Talat | 6. Dankhunto | | |
| | 7. Huaithalang* | 1. <u>SURIN</u> ⁺ | |
| 1. <u>KRONKAEN</u> ⁺ | 8. Jakaraj | 2. Chom Pra* | |
| 2. Ban Phai | 9. Karmthalasoa | 3. Chumburi | |
| 3. Chumphae | 10. Kong | 4. Pra Sat | |
| 4. Granuan | 11. Noasoong | 5. Ratana Buri | |
| 5. Manjakiri | 12. Noathai | 6. Samrong Thap | |
| 6. Namphong | 13. Pakchong | 7. Sangkha | |
| 7. Nong Song Hong* | 14. Paktrongchai | 8. Sikoraphum | |
| 8. Nong Rua | 15. Phimai | 9. Tha Thum | |
| 9. Phol | 16. Prathai* | | |
| 10. Phu Wiang | 17. Sikhiew | 1. <u>UDORN THANI</u> ⁺ | |
| | 18. Soongnern | 2. Ban Dong* | |
| 1. <u>LOEI</u> ⁺ | 1. <u>NONGKHAI</u> ⁺ | 3. Ban Phu | |
| 2. Chian Khan | 2. Bung-kan | 4. Kumhawapi | |
| 3. Dan Sai | 3. Phonphisai | 5. Nongbua Lamphu | |
| 4. Pukradung* | 4. Seka | 6. Nong Han | |
| 5. Tha Li | 5. Srichiangmai | 7. Non Sang | |
| 6. Wang Sapang | 6. Thabo | 8. Phen | |

and creates employment for some 30,000 laborers in about 200 baling plants for seven months of the year and for more than 12,000 workers in the twelve local bag mills on a year-round basis, and that largely in rural areas where few other industrial employment opportunities exist.

5.2. Thai Kenaf Planting Areas and Fiber Production

The overall annual record of the areas planted to kenaf since the inception of the industry in Thailand, the average retted fiber yield per rai and per hectare, and total fiber production are shown in Table II.11. and Figs. II.1. and II.2., where it is noted that it is often somewhat difficult to secure reliable statistics and that different sources of information do not always agree with each other as to such statistics, so that these and subsequent tables and figures include some compromise and adjusted data based upon reasonable approximations.

Table II.12. shows the annual kenaf planting area, by Changwat, for the 17-year period from 1958 to 1974; Table II.13. shows the annual kenaf planting area and the retted fiber production, by Changwat, for the 8-year period from 1967 to 1974, as well as the average annual planting area and production, by Changwat and overall, and the average retted fiber yield per rai and per hectare, again by Changwat and for Thailand as a whole; and Figs. II.3. and II.4. represent graphically the average annual kenaf planting area and kenaf fiber production, by Changwat, for the same most recent 8-year period from 1967 to 1974.

As will be seen, there have been wide fluctuations in the size of the annual kenaf crop ranging, for the last decade only, from a low of 184,000 tons in 1968, to highs of 622,000 tons and 625,000 tons in 1966 and 1973 respectively. Such fluctuations in crop production inevitably result in similar fluctuations in the price of the fiber. The area of land which the Northeast farmer devotes to kenaf planting has depended, in the past, to a considerable extent on the price he received for his fiber in the previous season (see Chapter V, Section 6.1.1. below); this, in turn, depended on both the previous year's local crop size as well as on the size of that year's jute crop in India and Bangladesh which latter, due to its preponderant position in the international jute, kenaf and allied fiber market, largely determines the world market prices of natural packaging material fibers. Thus, a good price in one season will lead to a large Thai kenaf crop in the following season which, if coincidental with a large jute crop in India and Bangladesh, will result in lower prices and, thus, a smaller kenaf crop the next following year, a cycle which perpetuates annual crop size and price fluctuations.

Table II.11.

Kenaf Area Planted, Yield per Unit Area and Kenaf Fiber Production,
Thailand, 1950 to 1974

Year	Area Planted		Average Yield		Production (1,000 Tons)
	'000 Rai	Ha.	Kg./Rai	Kg./Ha.	
1950	31	5,000	152	940	4.7
1951	88	14,000	67	421	5.9
1952	67	10,700	104	654	7.0
1953	60	9,600	138	865	8.3
1954	37	5,900	232	1,458	8.6
1955	53	8,500	185	1,153	9.8
1956	109	17,400	156	977	17.0
1957	78	12,500	228	1,424	17.8
1958	126	20,200	233	1,465	29.6
1959	275	44,000	180	1,136	50.0
1960	849	135,800	207	1,335	181.3
1961	1,207	193,100	201	1,239	239.3
1962	692	110,700	195	1,214	134.4
1963	925	148,000	229	1,430	211.7
1964	1,387	222,000	219	1,365	303.1
1965	2,191	350,600	247	1,500	529.1
1966	3,337	534,000	187	1,166	622.4
1967	2,548	407,700	191	1,196	487.8
1968	1,068	170,900	172	1,074	183.6
1969	1,943	310,900	177	1,109	344.7
1970	2,057	329,100	191	1,194	393.1
1971	2,538	406,000	196	1,223	496.7
1972	2,837	454,000	178	1,110	502.8
1973	3,436	550,000	182	1,136	624.7
1974	2,571	411,400	172	1,074	443.5

Source: Division of Agricultural Economics, Ministry of Agriculture

ANNUAL KENAF PLANTING AREA, THAILAND 1960 TO 1974

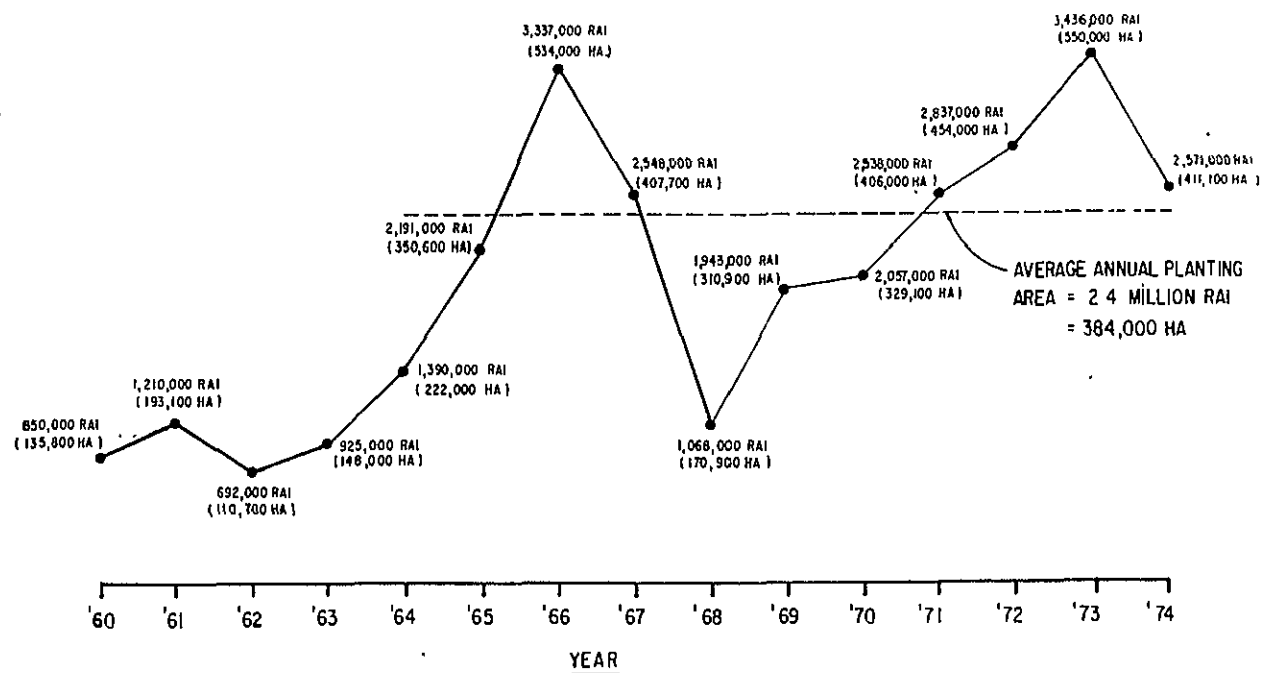


Fig. II.1.

ANNUAL KENAF FIBER PRODUCTION, THAILAND

1960 TO 1974

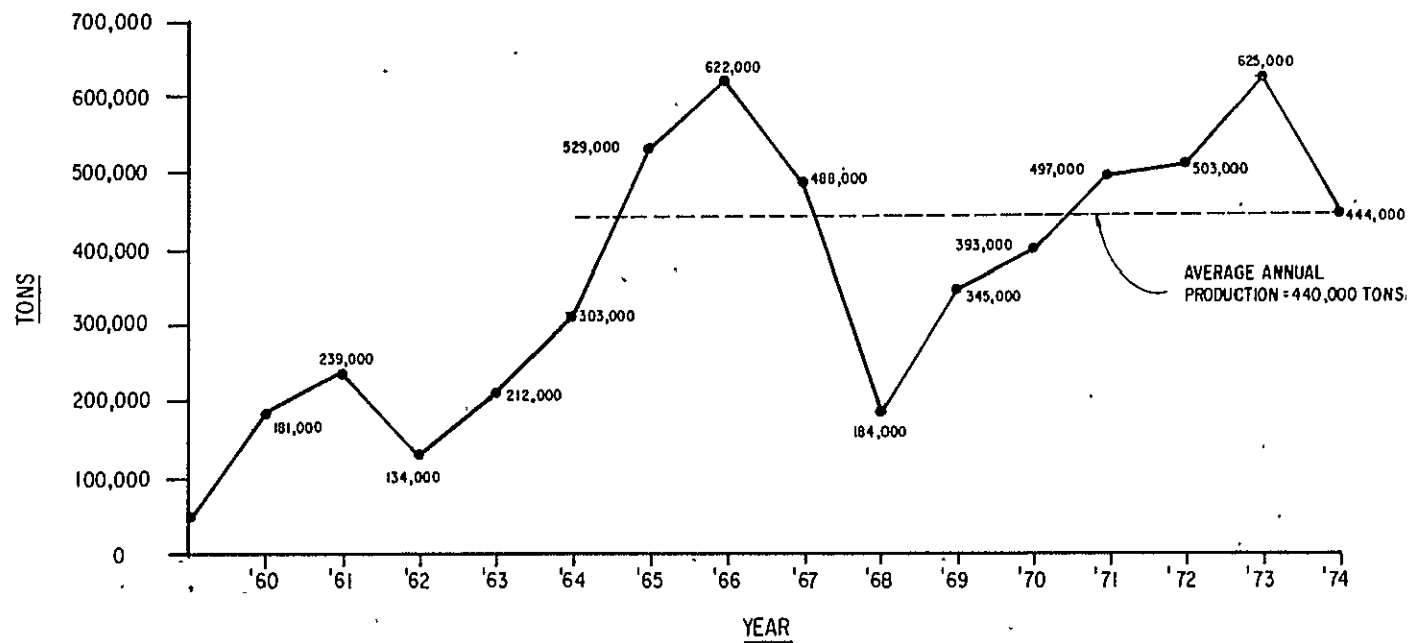


Fig. II.2.

Konaf Planting Areas, by Changwat, Thailand
1958 to 1974

Unit - Rai

Changwat	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Buriram	1,760	1,610	12,640	146,294	94,026	48,000	63,466	89,000	164,103	57,213	18,800	93,552	145,772	201,833	217,689	336,940	144,109
Chaiyaphoom	49,600	58,800	92,149	218,260	110,039	158,622	178,348	313,693	396,859	491,328	160,825	247,603	303,878	316,292	348,514	339,071	239,892
Kelasin	2,377	1,700	71,870	166,142	106,200	71,490	63,430	86,000	196,691	140,085	54,838	102,892	75,203	118,237	158,761	161,501	145,904
Khon kaen	9,127	31,728	73,134	105,512	96,769	126,192	299,398	450,235	666,941	408,147	124,313	318,156	380,710	434,455	367,436	347,942	291,177
Loei	55	60	510	950	774	700	6,392	5,000	29,655	14,321	2,740	17,191	38,125	34,251	101,508	114,674	95,695
Maharakam	23,771	136,896	152,608	353,043	121,859	211,738	266,359	398,754	467,682	349,819	186,938	378,434	313,588	383,442	368,168	410,026	299,225
Nakorn Phanom	2,544	562	760	32,434	12,032	11,298	10,107	16,576	33,144	58,068	38,434	40,545	24,461	28,333	29,489	57,462	32,675
Nakornrachasima	27,114	34,354	94,215	200,206	58,160	120,375	169,551	183,730	398,985	325,046	78,321	162,522	227,446	266,444	373,913	471,032	385,333
Nong Khai	209	208	220	250	2,300	5,000	2,500	4,000	20,000	21,429	1,652	3,475	2,577	15,439	11,112	30,756	14,226
Roi-Et	1,992	2,107	39,832	46,325	12,053	27,384	38,602	92,570	180,157	168,168	76,484	91,621	140,719	153,283	108,484	132,544	139,347
Sakorn Nakon	260	212	8,422	8,910	3,283	1,342	1,066	16,596	9,722	17,100	4,223	4,980	5,991	6,572	6,126	18,897	9,805
Sisaket	2,327	2,367	82,103	99,879	34,504	31,233	58,184	89,754	134,631	56,524	211,280	74,134	94,801	118,588	187,618	191,859	185,613
Surin	442	217	318	1,951	11,919	6,679	26,382	65,807	191,370	62,347	12,515	47,865	90,126	132,435	172,671	190,467	156,187
Ubon Ratchthani (1)	2,910	2,513	217,958	193,146	6,525	81,492	165,406	299,141	299,141	261,229	78,378	266,000	151,942	222,896	228,027	418,335	299,428
Udon Thani	1,380	1,374	2,543	33,478	21,269	23,259	38,154	79,646	147,620	116,918	18,595	93,670	61,223	107,841	132,115	214,618	126,761
Also:																	
Chiang Rai	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,467	14,596	5,817
Sakorn Savan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	140	17,836	206
Prachinburi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17,830	-	-
Total	Rai 125,868 Ma. 20,139	274,708 43,953	849,282 135,885	1,606,780 257,085	691,712 110,674	924,804 147,969	1,387,345 221,975	2,190,502 350,480	3,336,701 533,872	2,547,742 407,639	1,068,336 170,934	1,942,673 310,828	2,056,642 329,063	2,538,341 406,135	2,837,068 453,931	3,436,124 549,780	2,571,400 411,424

Note (1) Incl. Yasothon

Sources 1958 to 1967 Figures - Department of Agriculture
1968 to 1970 Figures - Department of Agricultural Extension
1971 to 1972 Figures - Division of Agricultural Economics
1973 to 1974 Figures - Thai Iute Association

Table II.12.

Kenaf Planting Areas and Production, by Changwat, Thailand
1967 to 1974

Changwat	1967		1968		1969		1970		1971		1972		1973		1974		Average - 1967 to 1974		
	Area (Rai)	Production (Tons)	Area (Rai)	Production (Tons)	Area (Rai)	Production (Tons)	Area (Rai)	Production (Tons)	Area (Rai)	Production (Tons)	Area (Rai)	Production (Tons)	Area (Rai)	Production (Tons)	Area (Rai)	Production (Tons)	Area (Rai)	Production (Tons)	Retted Fiber (kg./Rai)
Buriram	57,213	11,433	18,800	3,670	93,552	20,144	145,772	20,605	201,833	34,023	217,689	38,593	336,940	66,753	144,109	27,324	151,989	28,068	185
Chaiyaphoom	491,328	89,072	160,825	27,841	247,603	18,506	303,878	71,878	314,292	62,924	348,514	60,035	339,071	59,639	239,892	36,655	305,675	53,318	174
Kalasin	140,085	27,852	54,838	8,579	102,892	20,888	75,203	17,906	118,237	23,599	158,761	29,221	161,501	33,733	145,904	28,430	119,678	23,776	199
Khon Kaen	408,147	81,629	124,313	27,224	318,156	70,585	380,710	56,613	434,455	86,231	367,436	65,404	347,942	60,290	291,177	51,018	334,042	62,374	187
Loei	14,321	3,857	2,740	675	17,191	4,509	38,125	11,926	34,251	7,484	101,508	13,809	114,674	23,563	95,695	27,303	52,313	11,641	223
Maharakam	349,819	68,424	186,938	31,523	378,431	73,686	313,588	60,916	383,442	79,183	368,168	59,147	410,026	70,158	299,225	51,822	336,205	61,857	184
Nakorn Phanom	58,068	12,555	38,434	6,572	40,545	10,470	24,461	4,647	28,333	5,575	29,489	5,773	57,462	14,365	32,675	6,082	38,683	8,255	213
Nakorn Ratchasima	325,046	63,380	78,321	23,673	162,522	26,458	227,446	39,975	266,444	53,846	373,913	68,880	471,032	77,922	385,333	64,402	286,257	52,317	183
Nong Khai	21,429	2,486	1,652	204	3,475	672	2,577	411	15,439	3,387	11,112	2,830	30,756	6,952	14,226	3,166	12,583	2,514	200
Roi-Et	168,168	33,401	76,484	11,030	91,621	17,154	140,719	28,144	153,283	27,361	108,484	15,538	132,544	23,886	139,347	19,778	126,331	22,037	174
Sakorn Nakon	17,100	2,534	4,223	952	4,980	1,008	5,991	1,145	6,572	797	6,126	1,300	18,897	1,284	9,805	2,776	9,212	1,475	160
Sisaket	56,524	10,000	211,280	21,128	74,134	12,653	94,881	19,485	118,588	24,848	187,618	30,645	191,859	31,865	185,613	26,672	140,062	22,162	158
Surin	62,347	11,612	12,515	2,110	47,865	11,227	90,126	18,025	132,435	30,585	172,671	37,845	190,467	39,710	156,187	25,593	108,077	22,051	204
Ubon Ratchani ⁽¹⁾	261,229	46,400	78,378	14,116	266,000	45,486	151,942	30,179	222,896	39,094	228,027	43,231	418,335	65,408	299,428	46,535	240,779	41,306	172
Udon Thani	116,918	23,153	18,595	4,296	93,670	11,227	61,223	11,221	107,841	17,775	132,115	24,753	214,618	41,680	126,761	24,797	108,968	19,863	182
Also:																			
Chiang Rai	-	-	-	-	-	-	-	-	-	-	7,467	1,597	14,596	2,810	5,817	1,083	9,293	1,830	191
Nakorn Savan	-	-	-	-	-	-	-	-	-	-	140	14	17,836	2,665	206	46	6,061	908	150
Prachinburi	-	-	-	-	-	-	-	-	-	-	17,830	4,234	-	-	-	-	17,830	4,234	237
Total	Rai 407,639	2,547,742 487,794	1,058,336 170,934	183,593	1,942,673 310,828	344,673	2,056,642 329,053	393,076	2,538,341 406,135	496,712	2,837,068 453,931	502,849	3,436,124 549,780	624,683	2,571,400 411,424	443,482	2,404,038 384,646	438,986	-
Average Rettet Fiber Yield	Kg./Rai Kg./Ha.	191 1,196	172 1,074	177 1,109	191 1,194	196 1,223	178 1,110	182 1,136	172 1,074	184 1,150									

Note (1) Incl. Yasothon

Sources 1958 to 1967 Figures - Department of Agriculture
1968 to 1970 Figures - Department of Agricultural Extension
1971 to 1972 Figures - Division of Agricultural Economics
1972 to 1974 Figures - Thai Jute Association

AVERAGE ANNUAL KENAF PLANTING AREA, THAILAND

BY CHANGWAT — 1967 TO 1974

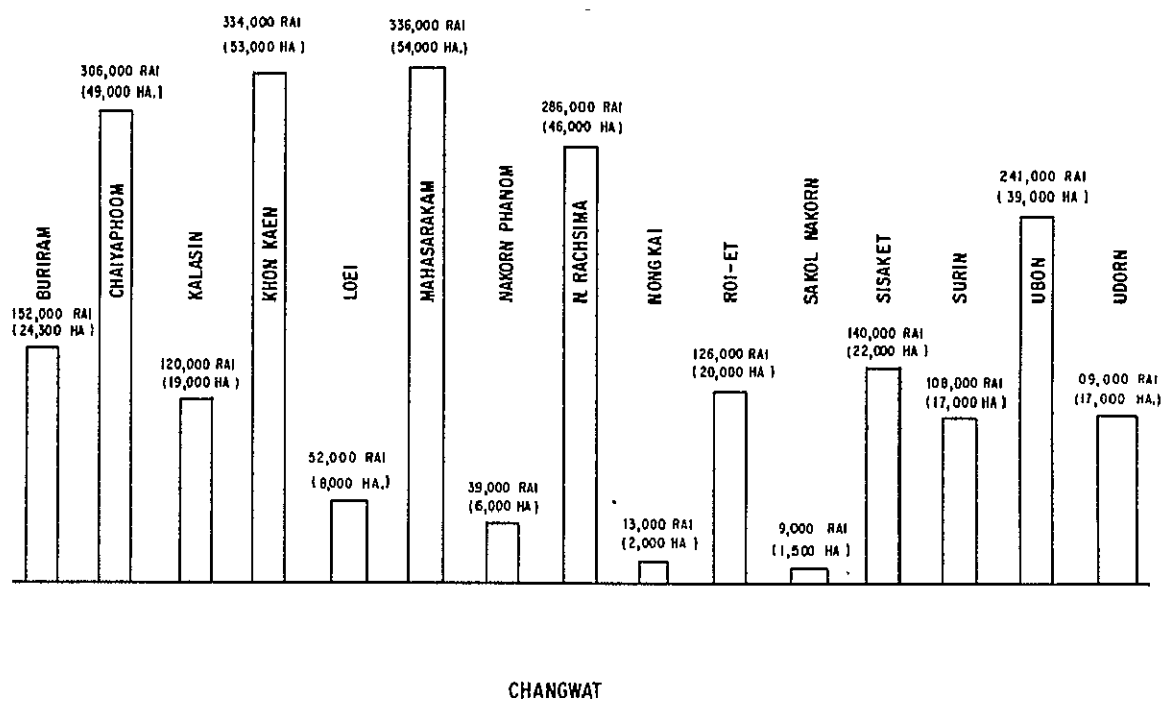
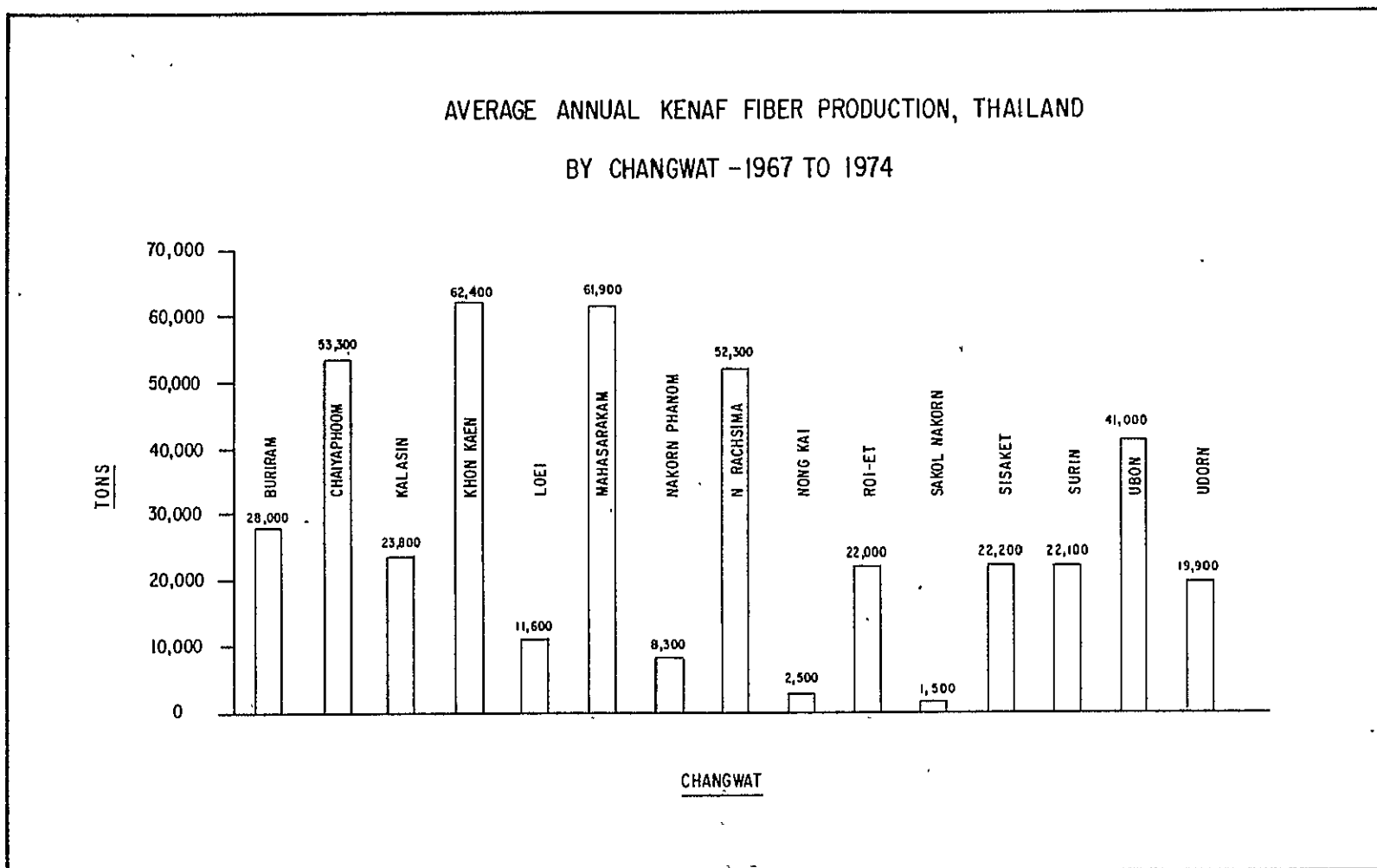


Fig. II.4.



Although Thailand, with its relatively small share in the international jute, kenaf and allied fiber market, can not exert any effective influence on world market prices, the level of which will continue to be controlled by the jute crop size and marketing policies of India and Bangladesh (see also Section 5.4. below), an improvement in average retted fiber quality and the more conscientious grading of export fiber could be expected to lead to a steadier overseas demand and a higher average price for good quality Thai kenaf fiber thus contributing to a levelling out of both the crop size and farm level fiber prices.

Whereas, in the past, an average retted fiber yield figure of 1,250 kg./ha. (200 kg./rai) has generally been accepted in Thailand, Table II.13. shows that this figure is no longer applicable and that an average yield assumption of, say, 1,150 kg./ha. (184 kg./rai) is more realistic, and this figure will be used for Northeast Thailand for purposes of area calculation and output estimation in this Study. This Northeast-wide average fiber yield reduction of some 9 percent is ascribed principally to the lack of an adequate kenaf research effort aimed at both variety improvement and the development of a H. sabdariffa variety resistant to phytophthora, a disease rapidly spreading in the kenaf areas of Northeast Thailand; the lack of a large-scale improved (extension) seed production program; and a general gradual soil fertility reduction due to the practically complete absence of soil conservation measures of any kind. However, programs aimed at arresting and reversing this downward yield trend through intensified research and seed improvement are under active consideration, both by the Thai bag mill industry and by Government with potential World Bank backing.

Table II.14. lists the average annual planting areas by Changwat for the 1967 to 1974 period in their order of magnitude. The listing shows that the five Changwats of:

Maharakam - Khon Kaen - Nakorn Ratchasima - Chaiyaphoom -
Ubon Ratchathani

between them account, on the average, for 63 percent (240,300 ha. - 1,502,000 rai) of the annual planting area in the Northeast; they have, in fact, been the major kenaf producing Changwats in the Northeast for the last fifteen years. Grouping the Changwats into geographical areas, it will be seen that the major "West-Central" Changwats of:

Udon Thani - Khon Kaen - Kalasin - Maharakam - Roi-Et -
Chaiyaphoom

Table II.14.

Average Annual Kenaf Planting Areas, by Changwat
In Order of Magnitude, Thailand, 1967 to 1974

Changwat	Area	
	Rai	Hectare
1. Mahasarakam	336,000	53,800
2. Khon Kaen	334,000	53,400
3. Chaiyaphoom	305,000	48,800
4. Nakorn Ratchasima	286,000	45,800
5. Ubon Ratchathani	241,000	38,600
6. Buriram	152,000	24,300
7. Sisaket	140,000	22,400
8. Roi-Et	126,000	20,200
9. Kalasin	120,000	19,200
10. Udorn Thani	109,000	17,400
11. Surin	108,000	17,300
12. Loei	52,000	8,300
13. Nakorn Phanom	39,000	6,200
14. Nong Kai	13,000	2,100
15. Sakorn Nakorn	9,000	1,400
<u>Also (1973 & 1974):</u>		
16. Prachin Buri	18,000	2,900
17. Chiang Rai	9,000	1,400
18. Nakorn Savan	6,000	1,000

together grow some 56 percent (212,800 ha. - 1,330,000 rai) of the total annually, whereas the "Southern Tier" Changwats of:

Nakorn Ratchasima - Surin - Sisaket - Buriram - Ubon Ratchathani

plant an average of 39 percent (148,300 ha. - 927,000 rai), and the remaining peripheral Changwats of:

Sakorn Nakorn - Nakorn Phanom - Nong Kai - Loei

plant the balance of 5 percent (18,100 ha. - 113,000 rai).

In early September 1975, a joint Ministry of Agriculture/Thai Jute Association Mission completed a survey of the kenaf crop in Northeast Thailand and estimated the following kenaf planting areas per Changwat:

<u>Changwat</u>	<u>Area (Rai)</u>
Buriram	87,000
Chaiyaphoom	302,000
Kalasin	67,000
Khon Kaen	262,000
Loei	n.a.
Mahasarakam	276,000
Nakorn Ratchasima	211,000
Nong Kai	14,000
Roi-Et	125,000
Sakorn Nakorn	9,300
Sisaket	124,000
Surin	144,000
Ubon Ratchathani	
(incl. Yasothon)	287,000
Udorn Thani	n.a.
Chiang Rai	1,500
Total	<u>1,946,800 Rai</u> <u>=====</u> (311,500 Ha.)

The Thai Jute Association members of the above mission felt, however, that the planting area figure should be reduced to 1,600,000 rai (256,000 ha.).

As of September 1975, the kenaf trade in Thailand also estimated that the 1975/1976 crop would amount to between 250,000 and 275,000 tons, where the lower figure was communicated to the Tenth Session of the Intergovernmental Group on Jute, Kenaf and Allied Fibers, held at the FAO, Rome, on May 21 to 23, 1975 (see Table II.16.).

If the lower planting area estimate of 1.6 million rai of the Thai Jute Association and the higher production estimate of 275,000 tons for the 1975/1976 season is accepted, this would mean an average production of only 171 kg./rai (1,069 kg./ha.) compared to 184 kg./rai (1,150 kg./ha.) average for the 1967 to 1974 period (Table II.13.). If that same somewhat low yield projection is applied to the Ministry of Agriculture estimate of a 1,946,800 rai planting area, the 1975/1976 production estimate would rise to 333,000 tons, and it would increase to 358,000 tons if the 1967 to 1974 average yield figure of 184 kg./rai (1,150 kg./ha.) was used. It may well be that actual 1975/1976 retted kenaf fiber production will lie somewhere between the above extremes, say around 300,000 tons, where the kenaf trade's lower estimate may have been influenced somewhat by wishful thinking, particularly since there was a 150,000 tons carry-over stock from the previous year at the beginning of September 1975 (100,000 tons in the Northeast and 50,000 tons in Bangkok).

5.3. Domestic Kenaf Fiber Demand in Thailand

Domestic kenaf fiber consumption in Thailand is made up of the requirements of the Thai bag and hessian mills and of village consumption, including any small twine, rope or other cottage industry.

Reliable statistics regarding both these demand sectors are difficult to obtain. In fact, no official information is available for village and cottage industry consumption and it can only be estimated on the basis of similar consumption estimates in India and Bangladesh and taking the population disparity into account.

With regard to the raw material consumption of the local bag and hessian mills, the official statistics do not necessarily always reflect the actual situation since: (a) a number of mills have, over the years, not divulged their full production figures in order to reduce their tax obligations, and (b) others expanded their production capacity without official sanction; however, this latter situation has now become regularized as a result of the Government's decision in 1974 to permit, subject to certain restrictions, the expansion of the existing mills and the establishment of new mills; as a result, a total of twelve bag and hessian mills and one twine mill will be in operation in Thailand by the end of 1975. It is the consensus of opinion of informed sources in the industry that their total raw material consumption will then be in the 220,000 tons per year range.

Table II.15. showing the local kenaf fiber consumption in Thailand for the 1952 to 1975 period has been prepared taking the foregoing reservations into consideration. Although finished goods production, specially in more recent years, is composed of yarn, B-Twill bags, hessian and other constructions in addition to the predominant Heavy-C bags, all production has been converted into Heavy-C bag equivalent in Table II.15. and an average raw material requirement of 1.25 kg. per bag has been used as a basis of calculation, composed of 1.13 kg. actual finished bag weight plus 10 percent mill wastage.

In Fig. II.5., the increase in local demand over the last 12-year period is shown graphically. Offsetting this annual demand against the estimated average annual Thai retted fiber production of 440,000 tons per year over the same period, the "Export Availability" curve has been established. It will be seen that such export availability has decreased from 89 percent of the total kenaf crop in 1964 to a projected 42 percent in 1975; conversely, local consumption has risen from 11 percent to 58 percent of the total crop over the same period.

Table II.15.

Local Consumption of Kenaf Fiber, Thailand
1952 to 1975

Year	Finished Goods Production (Million Bags) ⁽¹⁾	Mill Consumption ⁽²⁾ (Metric Tons)	Village, etc. Consumption ⁽³⁾ (Metric Tons)	Total Local Consumption (Metric Tons)
1952	1.0	1,250	4,000	5,250
1953	1.1	1,400	4,200	5,600
1954	1.2	1,500	4,400	5,900
1955	1.3	1,600	4,600	6,200
1956	3.5	4,400	4,800	9,200
1957	4.0	5,000	5,000	10,000
1958	4.6	5,750	5,200	10,950
1959	5.1	6,400	5,400	11,800
1960	6.9	8,600	5,600	14,200
1961	8.8	11,000	5,800	16,800
1962	10.9	13,600	6,000	19,600
1963	23.1	28,900	6,200	35,100
1964	33.5	41,900	6,400	48,300
1965	40.4	50,500	6,600	57,100
1966	46.8	58,500	6,800	65,300
1967	54.7	68,400	7,000	75,400
1968	66.8	83,500	7,200	90,700
1969	78.9	98,600	7,400	106,000
1970	95.4	119,200	7,600	126,800
1971	113.2	141,500	7,800	149,300
1972	132.5	165,600	8,000	173,600
1973	147.0	183,800	8,200	192,000
1974	161.6 ⁽³⁾	202,000	8,400	210,400
1975	176.0 ⁽³⁾	220,000	8,600	228,600

Note: (1) Converted into No. of Heavy-C Bag Equivalent

(2) Assuming 1.25 kg./Heavy-C Bag (weight = 1.13 kg. + 10% fiber wastage in mill)

(3) Estimated

Sources: Bank of Thailand
Department of Customs
National Economic Development Board

KENAF FIBER PRODUCTION, LOCAL CONSUMPTION AND EXPORT AVAILABILITY, THAILAND 1964 TO 1975

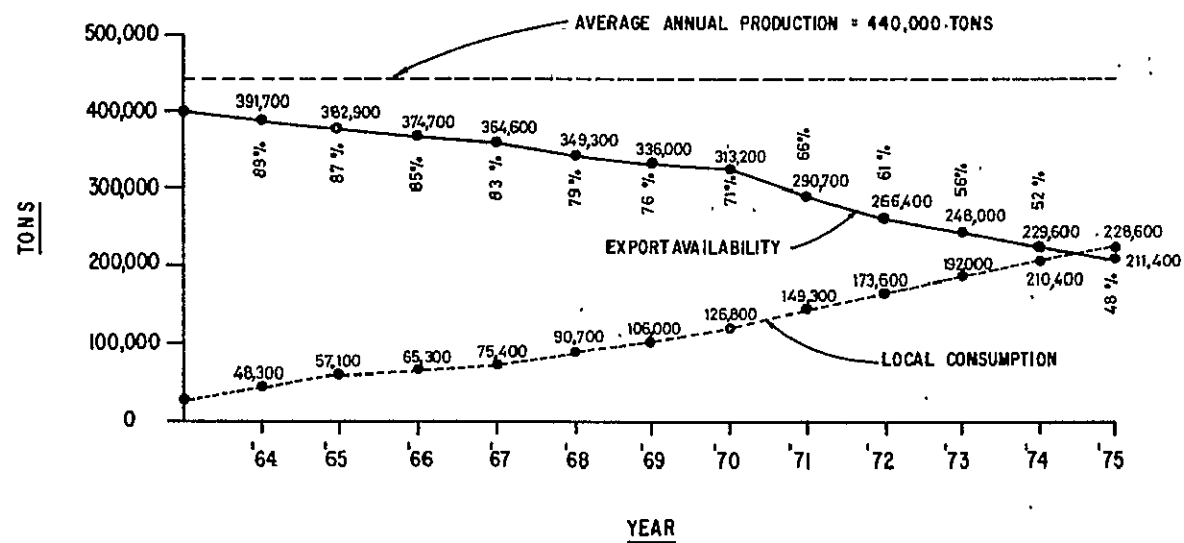


Fig. II.5.

A levelling off in domestic kenaf fiber demand is anticipated as far as the immediate future is concerned, since it is felt that the end-1975 installed capacity of the local mills will be adequate to satisfy projected domestic and export demand for some time to come.

In Fig. II.5., an average annual retted kenaf fiber production of 440,000 tons is assumed; however, as of January 1, 1976, the Thai kenaf traders estimated the 1975/1976 kenaf crop at only 250,000 tons maximum and this estimate has been given wide publicity. In addition, it is claimed that two-thirds of the previous crop carry-over consisted of cuttings and tangles and only of 50,000 tons of line fiber. In view of local requirements in the 230,000 tons range, this would leave a very maximum line fiber export availability of 80,000 tons during the 1975/1976 season, by far the lowest such availability for the last 15 years.

5.4. The Thai Kenaf Fiber Export Market

In view of the fact that Thailand's annual kenaf fiber production has, during the last decade, represented only a little more than 12 percent of the total world production of jute, kenaf and allied fibers and less than 20 percent of the production of the two principal producers, India and Bangladesh, the world-wide production and consumption trends of these fibers must be examined in order to establish the position of the Thai kenaf fiber industry within the overall framework of the world fiber market and to project its future potentials.

The discussion in this section is based on the documentation submitted by its Secretariat to the Tenth Session of the Intergovernmental Group on Jute, Kenaf and Allied Fibers, held at the FAO, Rome, on May 21 to 23, 1975. Tables II.16., II.17. and II.18. are reproductions or condensations of some of the statistical information presented to the Session, and the portions of the report issued by the Secretariat which affect the Thai kenaf industry are summarized and commented upon herein.

Table II.16. shows the relationship between Thailand's kenaf (and true jute) production and the overall world total for the years 1961/1962 to 1974/1975 as follows:

Year	P r o d u c t i o n		
	World (000 MT)	T h a i l a n d	
		(000 MT)	(% of Total)
1961/62 to 1965/66	3,336	291 (284)	9
1966/67 to 1970/71	3,433	350 (406)	10 (12)
1971/72	3,280	350	11
1972/73	3,947	400 (517)	10 (13)
1973/74	4,710	660	14
1974/75	3,820	389	10

It should be noted that the FAO statistics show lower annual production figures for kenaf in Thailand than those of the Thai Ministry of Agriculture (Table II.11.). The revised Thai tonnages and percentages are shown in brackets in the above listing.

Table II.16.

Estimated World Production of Jute, Kenaf and Allied Fibers
1961/1962 to 1975/1976

Country	Fiber	1961/62 to 1965/66	1966/67 to 1970/71	1971/72	1972/73	1973/74	1974/75 (Est'd)	1975/76 (Forecast)
(..... thousand metric tons)								
Bangladesh	Jute	1,123	1,173	755	1,170	1,087	720	684
	Kenaf	37	38	17	20	20		
India	Jute	1,026	907	1,022	896	1,112	810	1,080
	Kenaf	293	208	203	200	263	180	
Thailand	Jute	8	10	10	10	660	389	250
	Kenaf	283	340	340	390			
Nepal	Jute	25	41	55	55	57	50	
Burma	Jute	10	20	65	90	88	58	
	Kenaf	1	1	1	1			
Indonesia	Kenaf	5	12	14	13	18	17	
Iran	Kenaf	4	3	2	3	2	2	
Khmer Republic	Jute/Kenaf	2	5	7	5	-	-	
Other Asia	Jute	14	16	3	-	-	-	
	Kenaf	5	5	-	-	-	-	
<u>Total Asia</u>		<u>2,841</u>	<u>2,780</u>	<u>2,494</u>	<u>2,853</u>	<u>2,307</u>	<u>2,226</u>	
Brazil	Jute	48	35	22	22	32	70	
	Malva/Guaxima	16	22	40	43	46		
Peru	Jute	2	4	9	10	6	4	
El Salvador	Kenaf	2	4	4	4			
Cuba	Kenaf	2	4	5	7			
Other Latin Amer.	Kenaf	3	3	3				
<u>Total Latin America</u>		<u>73</u>	<u>72</u>	<u>83</u>	<u>90</u>	<u>100⁽¹⁾</u>	<u>90⁽¹⁾</u>	
Egypt	Kenaf	1	3	12	15	8	8	
Zaire, Rep. of	Urena/Punga	7	7	8	5			
Mozambique	Kenaf	2	5	6	4	5		
Angola	Kenaf/Urena/Punga	2	2	2	1	1		
Nigeria	Kenaf	-	2	3				
Dahomey	Kenaf	-	-	2				
Madagascar	Urena	2	2	2	2	2		
Other Africa	Kenaf	-	-	4	4			
<u>Total Africa</u>		<u>14</u>	<u>21</u>	<u>39</u>	<u>40</u>	<u>33⁽¹⁾</u>	<u>34⁽¹⁾</u>	
China	Jute	119	174	225				
	Abutilon/Kenaf	234	323	375	900	1,200	1,400	
USSR	Kenaf	41	46	46				
Viet-Nam, Dem. Rep.	Kenaf	14	17	18				
<u>Total, Centrally Planned Countries</u>		<u>408</u>	<u>560</u>	<u>644</u>	<u>964</u>	<u>1,270</u>	<u>1,470</u>	
<u>World Total</u>		<u>3,336</u>	<u>3,433</u>	<u>3,280</u>	<u>3,947</u>	<u>4,710</u>	<u>3,820⁽¹⁾</u>	
of which	Jute	2,379	2,386	2,170				
	Allied Fibers	957	1,047	1,110				

(1) Estimated

Source: Intergovernmental Group on Jute, Kenaf and Allied Fibers, FAO, Rome

Estimated Jute, Kenaf and Allied Fiber Supplies, Domestic Requirements,
Exports and Imports, 1974/1975

Item	Bangladesh (. thousand metric tons)	Thailand	India	Other Countries	World
Opening Stocks	414	248	684		
Production	720	391	990	1,721	3,822
Imports	-	-	18	595	613
<u>Total Supply</u>	<u>1,134</u>	<u>639</u>	<u>1,692</u>		
Mill Consumption	468	202	1,134		
Village Consumption	36	8	36		
Closing Carryover	360	278	450		
<u>Total Domestic Reqts.</u>	<u>864</u>	<u>488</u>	<u>1,620</u>		
<u>Exports</u>	<u>270</u>	<u>151</u>	<u>72</u>	<u>72</u>	<u>565</u>

Source: Intergovernmental Group on Jute, Kenaf and Allied Fibers, FAO, Rome

Table II.17.

Forecast of Jute, Kenaf and Allied Fiber Supplies, Domestic Requirements,
Export Availabilities and Import Requirements, 1975/1976

Item	Bangladesh (. , thousand metric tons)	Thailand	India	Other Countries	World
Opening Stocks	360	278	450		
Production	810	315	1,080		
Import Requirements Forecast	-	-	-	574	574
<u>Total Forecast Supply</u>	<u>1,170</u>	<u>593</u>	<u>1,530</u>		
Mill Consumption	540	220	1,260		
Village Consumption	36	9	36		
Closing Carry-Over	126	164	234		
<u>Forecast Domestic Reqts.</u>	<u>702</u>	<u>393</u>	<u>1,530</u>		
<u>Forecast Export Availab.</u>	<u>468</u>	<u>200</u>	<u>-</u>	<u>72</u>	<u>740</u>

Source: Intergovernmental Group on Jute, Kenaf and Allied Fibers, FAO, Rome

Table II.18.

Tables II.17. and II.18. estimate the jute and allied fiber supply and demand situation for 1974/1975 and 1975/1976. It will be seen that the forecast for 1975/1976 is an overall world import requirement of 574,000 tons versus export availabilities of 740,000 tons so that supplies are expected to be more than adequate to meet requirements. Output of the three main producing countries combined is forecast at 2,205,000 tons, slightly more than the previous year. Bangladesh expects the 1975/1976 crop to increase from the low level of 1974/1975 to 810,000 tons, while India estimates that its production would be about 1,080,000 tons. Thailand forecasts a production of 315,000 tons, somewhat less than in 1974/1975*. Nepal expects its output to remain at about the same level as the previous year. There appear to be only limited prospects for a recovery in demand in 1975/1976 and this together with the considerable stocks in the hands of consumers, is likely to cause a further drop in import requirements in 1975/1976 and, as stated, export availabilities are expected to be in excess of import requirements.

In view of the foregoing facts and considerations, the Intergovernmental Group on Jute, Kenaf and Allied Fibers was unable to reach a consensus, at its May 1975 Session in Rome, as to future industry development forecasting and this, obviously, includes forecasts of future Thai kenaf fiber export trends. Hence, this Study can, at best, only submit a few data and assessments for evaluation.

Table II.19. shows the export quantities and values of Thai kenaf for the 1957 to 1974 period. The table indicates that, during recent years, Thailand has regularly been able to export from 220,000 to 300,000 tons annually and that in spite of the fact that, during the same period, total world production of jute, kenaf and allied fibers remained almost constant (Table II.16.) and consumption in the developed countries (Western Europe, United States, Japan) progressively decreased. This supports the argument that, at least in the recent past, the reduction in demand for Thai kenaf in the developed countries was offset by a rise in demand in the developing world. One factor encouraging the substitution of some of the jute fiber traditionally used in the bag and hessian mills in the latter countries was the substantial price differential in favor of Thai kenaf vis-a-vis jute, e.g. as of August 1975:

* In Table II.16., the 1975/1976 production forecast for Thailand is shown at only 250,000 tons (see also Section 5.2. of this Chapter II).

Table II.19.

Export Quantities and Values of Thai Kenaf
1957 to 1974

Year	Metric Tons	Value	
		Million Baht	Million Dollars
1957	14,580	46	2.3
1958	27,587	70	3.5
1959	37,317	88	4.4
1960	61,769	230	11.5
1961	143,477	626	31.3
1962	237,898	579	29.0
1963	125,753	358	17.9
1964	162,095	495	24.8
1965	316,986	1,102	55.1
1966	473,269	1,614	80.7
1967	317,094	866	43.3
1968	289,478	674	33.7
1969	255,978	780	39.0
1970	257,663	719	36.0
1971	271,676	935	46.8
1972	255,093	1,087	54.4
1973	263,850	1,052	52.6
1974	218,974	788	39.4

Source: Thai Jute Association

Bangladesh - B.W.D. - Lst. 188.00
Thai Kenaf - Thai "A" - Lst. 133.00,

both on a CIF Main European Ports basis, where Thai "A" is usually considered equivalent to B.W.D. as far as the manufacture of, say, gunny bags is concerned.

The above appears to justify a prediction that export sales of Thai kenaf might be maintained at about the 200,000 to 250,000 tons per year level for the foreseeable future. On the other hand, some authorities foresee a gradual but steady decline in overall world demand for jute and allied fibers as a result of the continuing encroachment of the synthetic fibers, a decline which would obviously affect the export of Thai kenaf. Even the Thai kenaf market in the developing countries, only recently captured from jute, might well be endangered in view of (a) the development of local kenaf fiber production and (b) the installation of synthetic bag mills, as has already happened in a number of these countries.

Taking the various foregoing arguments and estimates into consideration, this present submission will assume an average export potential forecast of 175,000 tons of Thai kenaf fiber annually over the next ten-year period. Referring then to Fig. II.5. and assuming a levelling off of domestic demand at, say, 230,000 tons per year, it will be seen that a continued average annual retted fiber production of 440,000 tons - the rate maintained over the last decade - would make fiber exports at that level readily possible. Furthermore, if export demand should indeed prove to remain as high as 250,000 tons per year, such demand could be satisfied by an increase in planting area of only 35,200 ha. (220,000 rai)(9 percent). The Government is already taking steps to provide the additional incentives to the kenaf growers to increase fiber production so as to assure adequate supplies for both the domestic and export markets, as well as to increase farm income in the Northeast.

5.5. Jute Production in Thailand

Jute was grown in the Central Plain of Thailand since the 1940's, particularly in Changwats Ayuthya and Nakorn Sawan, and several thousand tons were exported annually until the mid-1950's when production started to decline due to pressure on the land for rice production, the low yield obtained from the local unimproved varieties, and uncertain prices for the fiber; this in spite of the fact that the jute was cultivated on alluvial soils along the rivers which offer optimum growing conditions for the crop.

The interest in jute production in Thailand revived in 1969 and 1970 and rose further in the following year due to the world shortage of that fiber as a result of the Indo-Pakistan War and the disturbances preceeding that event in what is now Bangladesh. It was then felt opportune to promote its greatly expanded production in view of the favorable market conditions and prices, and the Thai Jute Association became actively involved in the project. Some of the standard Indian jute varieties had been introduced into Thailand in 1966, presumably D154 of Corchorus capsularis and Chinsura Green of Corchorus olitorius; subsequently, a small quantity of the improved JRO 632 variety of C. olitorius was obtained and the seed multiplied.

The Thai Jute Association encouraged farmers in Nakorn Sawan to grow the C. capsularis variety in 1970. Unfortunately, the results were unsatisfactory, partly due to the lack of interest and expertise of the farmers and partly because of exceptional flood conditions. It was then decided to promote jute production in the following year in the Northeast where the farmers are already familiar with the cultivation and processing of kenaf which follows similar lines of that of jute. Accordingly, the Thai Jute Association distributed 2,000 kg. of JRO 632 variety seed to farmers in Udorn in 1971. The seed distribution was done through kenaf baling plants which, in turn, undertook to purchase the jute fiber produced at a guaranteed price of ฿1.00/kg. (US\$0.05/kg.) higher than the prevailing price for kenaf. The farmers were also requested to sell the seed crop to the balers for use in the following year's plantings. As a result of the farmers' unfamiliarity with the specific problems of growing jute - as opposed to kenaf - only 700 tons of fiber were assembled by the balers who, however, succeeded in purchasing 20 tons of seed from the growers. In spite of the lack of success of the 1971 program, the interest of the farmers in the Udorn area in jute production persisted due to potentially higher yields obtainable and the ฿1.00/kg. price mark-up. Udorn or rather selected areas in this and the neighboring Changwats have the

advantage of earlier rains than the more southern portions of the Northeast which is of importance to successful jute production in the region. At the same time, intensive promotional and extension activities were undertaken by the Ministry of Agriculture, the Thai Jute Association, the Siam Gunny Company (which groups all the bag mills in Thailand), and the Self-Help Resettlement Division of the Department of Public Welfare. As a result of these coordinated efforts, close to 9,000 tons of retted jute fiber were produced in Changwats Udorn Thani and Nong Khai and an average yield of 300 kg. of retted fiber per rai (1,875 kg./ha.) was achieved (as compared to 184 kg./rai = 1,150 kg./ha. for Thai kenaf). During the 1972/1973 season, the farm level price for kenaf averaged ฿3.00(US\$0.15)/kg. and, with the ฿1.00 agreed mark-up, that for jute averaged ฿4.00(US\$0.20)/kg. resulting in the following respective gross revenues:

Kenaf = 184 kg./rai at ฿3.00 = ฿552/rai (US\$172.50/ha.)
Jute = 300 kg./rai at ฿4.00 = ฿1,200/rai (US\$375.00/ha.)

In view of this favorable revenue comparison and although jute is somewhat more difficult to process than kenaf, the Udorn Thani and Nong Khai growers substantially increased their planting areas in the following year and produced close to 20,000 tons of retted jute fiber during the 1973/1974 season. Jute production outside of these two Changwats was minimal, primarily due to unfavorable rainfall conditions, and even in Udorn Thani and Nong Khai it was reduced by some 50 percent in 1974/1975, as was kenaf production in the Northeast as a whole during that (and the 1975/1976) season.

There is no question that a reasonably large annual jute production program could be instituted in the northern Changwats of Northeast Thailand as well as in those parts of Changwats Chaiyaphoom, Buriram, Surin, Sisaket and Ubon Ratchathani where soil conditions are favorable, say of the order of 100,000 tons of retted fiber annually. However, the successful implementation of such a program would require intensive research and extension work, selected seed production and distribution, the provision of additional retting facilities, the availability of farm credit, and the imposition of an effective grading and quality control program.

CHAPTER III - KENAF AGRONOMY AND FIBER PRODUCTION

1. Introduction

As stated previously, the term "Kenaf" covers two closely related fiber plant species, Hibiscus sabdariffa (H. sabdariffa - South Asian Kenaf) and Hibiscus cannabinus (H. cannabinus - Western Hemisphere Kenaf). Although the fiber characteristics - and, presumably, the pulping characteristics, a fact still to be definitively confirmed - of both species are very similar, substantial differences exist as far as their agronomics are concerned.

In this chapter, an overview of the general agronomy of kenaf for textile fiber production will be presented and different methods of such production, as practiced both within and outside the Lower Mekong Basin area, will be discussed so as to provide an understanding of the traditional methods of kenaf production upon which a potential future kenaf for paper pulp production program will have to be based, a program which will be described in detail in Chapter V. For South Asian kenaf, standard practices in Northeast Thailand - the predominant actual and potential future production area of this kenaf species in the riparian countries - are cited.

2. Kenaf Agronomy

2.1. South Asian Kenaf

- Climate and Soils

South Asian or Thai kenaf (Hibiscus sabdariffa L. var. altissima) is considered to be a tropical crop. The species resists drought reasonably well and can be grown where rainfall conditions are poor or under unfavorable rainfall distribution patterns such as prevail in some years in Northeast Thailand. The soils in the area are generally of low fertility, particularly those of the uplands, but will nevertheless produce adequate yields of kenaf fiber where most other crops will fail.

- Land Preparation

The seed of South Asian kenaf being very small, thorough soil preparation before planting is essential in order to assure proper germination and uniform growth. Plowing and raking is usually started during the first half of April, after the initial brief rain showers. For optimum results, those operations should be repeated at least twice before planting, at two or three weeks intervals.

Practically all farmers still use animal drawn implements. The wooden plows usually will not penetrate more than 6 inches below the surface, but this is generally considered sufficient in the sandy to very sandy upland soils used for growing kenaf in Northeast Thailand. For harrowing, a wooden rake is used; although it, too, is not designed for deep working of the soil, it does an adequate job provided it is conscientiously employed. Mechanization of agricultural operations in Northeast Thailand is progressing only slowly, although a number of private entrepreneurs rent out tractors for contract plowing, power tillers have begun to make their appearance, and some farmer groups own a limited amount of mechanical equipment.

- Planting

Kenaf is a photoperiodic plant. This means that it grows vegetatively during periods of long daylight and will flower when the length of daylight falls below a certain minimum in the autumn. H. sabdariffa starts flowering in Northeast Thailand about the middle of October. Since the yield of kenaf fiber - and the stalk weight - increases in direct proportion to the vegetative development of the plant, seeding should be done as early as possible in order to permit the maximum time for stalk growth before it is halted by the onset of flowering. Thus, planting should be started after the first rains in late April or early May and should be completed not later than the first half of June.

Most of the kenaf is still sown broadcast resulting in uneven stands, reduction in fiber - and stalk - yield, and lack of uniformity of fiber quality. Other farmers plant their seed in holes or "hills" made either with a hoe or a stick; although this method is superior to broadcast seeding, it leads to crowding of the seedlings in the hills and an inefficient use of the land. By far the best planting method is row planting which increases yields by up to 25 percent and results in substantially improved fiber quality. The optimum inter-row distance for textile fiber production is 30 cm. under Northeast Thailand conditions.

- Intercultural Operations

Weeding at the proper time and intervals is essential for high yields of good quality fiber. Since it is a time and labor consuming operation, it is often neglected by the kenaf farmer. It is particularly laborious in broadcast sown fields or in fields where the kenaf has been hill planted without placing the hills in rows. The ease of weeding row planted kenaf is one of the major advantages of this planting method.

In view of the small size of H. sabdariffa seed, a fairly heavy application is required to assure adequate germination and a uniform stand, but this leads to crowding of the young seedlings. In order to obtain tall and healthy plants of adequate stalk diameter, each plant must have sufficient room to grow. The superfluous plants are removed by "thinning". Ideally, a plant-to-plant distance of 7 to 10 cm. should be aimed at. Again, this operation is greatly facilitated in row plantings.

- Fertilization

The application of chemical fertilizer is not widespread on the kenaf farms in Northeast Thailand (manuring and compost spreading is practically unknown). The cash return from the use of fertilizer depends largely upon the farm level price for kenaf fiber. Since it has been found that fertilizer application on H. sabdariffa under Northeast conditions increases fiber yields by only 25 percent at best, a farm price of less than ฿3.30/kg. (US\$0.165/kg.) for "Mixed Grade" fiber makes it uneconomical (see Chapter V, Section 2.4.1.).

If used, chemical fertilizer is commonly applied in two equal doses, 30 and 60 days after germination respectively. No fertilizer is applied prior to planting or at the time of planting, as is practiced in a number of other kenaf production areas.

- Pests and Diseases

South Asian kenaf is remarkably pest and disease resistant and, so far, they have posed no serious problem in Northeast Thailand, although a number of both pests and diseases have been identified. Some inroads have, however, been made by collar rot and further work on the development of resistant varieties is required. Fortunately, H. sabdariffa is resistant to root-knot nematodes which otherwise could cause considerable damage in the light soils prevailing in the region.

- Crop Rotation

Almost no crop rotation is presently being practiced by the Thai kenaf growers leading to an undesirable level of nematode incidence and a high infestation rate of certain harmful soil fungi as well as to progressive depletion of soil fertility. Desirable rotation crops would be green manures, pulses and beans, or sunn hemp (Crotalaria juncea).

- Harvesting

Basically, kenaf should be harvested when it starts flowering - about mid-October in Northeast Thailand - at which time the stalks contain the maximum quantity of fiber of good quality. However, most farmers start cutting their stalks earlier since adequate retting water is then available; the land can be used for a second crop such as water melons; the kenaf harvest can be completed before the start of the rice harvest at the beginning of December; fiber prices are often higher at that time than during the main harvesting season; or because the farmer is in urgent need of cash.

For kenaf for paper pulp production and where the whole stalk is to be used, the harvest period can be both extended and adjusted so as not to interfere with the all-important rice harvest and to eliminate competition for harvesting labor. As discussed subsequently in this Study, the delayed harvest should also increase whole stalk yields as well as reduce ash and sugar content without adverse effect on fiber quality for pulping purposes.

For textile fiber production, the kenaf stalks are either cut with a bushknife or pulled out of the ground, the latter particularly in sandy soils. The stalks are then bundled and shocked in the field in order to allow the leaves to dry out and fall off.

Tests have shown that freshly cut kenaf stalks have a moisture content of between 65 and 75 percent depending upon the harvest period; during the dry season, field shocked stalks lose moisture rapidly and become field dry (12½ percent moisture content) within 10 to 15 days.

2.2. Western Hemisphere Kenaf

- Climate and Soils

Western Hemisphere kenaf (Hibiscus cannabinus L.) is grown approximately between 30 degrees north and south of the Equator but, like its related South Asian species (H. sabdariffa), is considered essentially a tropical crop and most of its production is concentrated in the tropics, primarily in Africa and Latin America. Although it, too, requires only moderate amounts of water compared to most other crops, it is somewhat less drought resistant than South Asian kenaf. Minimum rainfall requirements are approximately 125 mm. (5 in.) of rain per month during the first three months of its growing period but only a minimal requirement during the fourth month when the plants will normally start to flower.

H. cannabinus, with its shorter growth cycle and higher yield per unit area, also requires somewhat better quality soils than H. sabdariffa, although it will still produce an economic crop on fairly marginal soils. In particular, it is susceptible to root-knot nematodes so that light sandy soils are not suitable. In the riparian countries, it should be grown on intermediate fertility soils, preferably sandy loams or clay loams but with good drainage, with the more fertile soils being reserved for food and/or higher value crops. An attempt will be made in the next following Chapter IV to more closely identify potential Western Hemisphere kenaf production areas within the basin from a soil quality point of view, although the majority of those areas are presently inaccessible to the project team.

- Land Preparation

Traditional land preparation methods, whether for lowland or for upland crops, being similar in the four countries covered by this Study, much of such preparation in future H. cannabinus production in the Lower Mekong Basin area will duplicate the methods used in Northeast Thailand as described in the last previous section. Again, it is important that a fine tilth seed bed is prepared, although Western Hemisphere kenaf seed is not nearly as small as South Asian kenaf seed. However, it is planted much less densely and a thoroughly broken up soil will greatly facilitate uniform germination.

In view of the desirable heavier soil types, mechanized land preparation with tractor drawn implements is preferable for the planting of this kenaf species. It should consist of at least one plowing and cross-plowing followed by one or more harrowings and cross-harrowings. A further harrowing operation immediately prior to planting is essential in order to ascertain that the weeds will not have a headstart on the kenaf seedlings.

- Planting

Like its South Asian cousin, Western Hemisphere kenaf is photo-sensitive. However, a considerable amount of research and development work, particularly in Cuba and Guatemala, has resulted in the commercial availability of several H. cannabinus varieties with different photo-periods providing wide flexibility as far as the species' planting and harvesting dates are concerned and this point will be discussed in greater detail in Chapter V, Section 2:2.2. Suffice it to state here that it can be planted at any time after the start of the rains and that planting can continue until the latter part of the rainy season where the less photo-sensitive varieties would be planted last. In the (unlikely) event that irrigation facilities are made available, H. cannabinus could be planted practically on a year-round basis in the riparian countries.

Since Western Hemisphere kenaf is produced almost exclusively on an organized rather than a traditional scale in its principal growing areas (Latin America, Africa), it is practically always row planted, mostly by tractor drawn seed drills but occasionally also with the help of seeding rakes such as have been used in Viet-Nam in the past (see Chapter II, Section 4).

H. cannabinus is a much faster developing plant than H. sabdariffa and will grow at an average rate of about 2.5 cm. (1 in.) per day under reasonably favorable conditions; also, the leaves of most commercial H. cannabinus varieties are palmate (large solid surface) compared to the deeply lobed (indented, finger-like) leaf shape of H. sabdariffa. The combination of these two factors allows even the fairly young seedlings (20 to 25 days from date of planting) to generate a dense leaf "carpet" which shades out the soil underneath and thus eliminates weed competition. Hence, Western Hemisphere kenaf is planted at much closer inter-row spacings than South Asian kenaf, namely 17 to 20 cm. (7 to 8 in.) compared to 30 cm. (12 in.). Such closer spacing is both

desirable since it increases plant population and thus yield, and necessary to assure the leaf shading effect.

- Intercultural Operations

If H. cannabinus is planted as described above and provided excessive weed competition is eliminated through a harrowing operation immediately prior to planting, the kenaf will outgrow and outshade the weeds and no weeding at all will be necessary during the entire growth period. At the same time, the leaf shade will destroy the less vigorous and slower growing seedlings thus providing automatic thinning of the plants in the row which, in view of the larger seed size, are in any case planted less densely than the H. sabdariffa seedlings.

The elimination of two of the most labor intensive and costly operations in South Asian kenaf (and jute) production, namely weeding and thinning, is one of the major advantages of Western Hemisphere kenaf, from the point of view of both production economics and production convenience.

- Fertilization

H. cannabinus is highly responsive to fertilizer, particularly nitrogen and, although the establishment of exact fertilizer requirements can only be the result of soil analyses in the individual production areas, some 200 kg. of urea plus 200 kg. of, say, a 15-15-15 NPK compound per hectare will substantially increase its yield.

In view of the impracticability of applying fertilizer in the closely spaced rows after the crop is established, it is usually spread a few days before planting or applied at the time of planting. Since H. cannabinus is normally planted on somewhat heavier soils, the fertilizer loss through leaching is minimized.

- Pests and Diseases

Western Hemisphere kenaf, like South Asian kenaf, is not now subject to commercially important pests and diseases; nevertheless, some of those affecting both species are discussed in Chapter V, Section 2.6. However, it is susceptible to root-knot nematodes which are particularly prevalent in sandy soils such as are common in Northeast Thailand, and this nematode susceptibility must be kept in mind when selecting potential planting areas. It was one of the major reasons why previous attempts at the introduction of H. cannabinus into the Northeast failed.

- Crop Rotation

A crop rotation program is of particular benefit to Western Hemisphere kenaf, the continuous cultivation of which on the same land would otherwise lead to an excessive build-up of nematodes, soil fungi, etc. Any green manure crop would be suitable as would a number of others, with the obvious exception of such nematode prone crops as tobacco, tomatoes and potatoes.

- Harvesting

For textile fiber production, both kenaf species should be harvested at the time of flowering as already mentioned in the previous Section 2.1., where H. cannabinus reaches the flowering stage much earlier (120 to 125 days after planting) than H. sabdariffa (150 to 160 days) but where, thanks to the availability of a range of varieties with different photoperiod responses, it offers more flexibility as to optimum harvesting dates which, in turn, will further vary depending upon the type of raw material (whole stalk or bast ribbon) the pulp mill will require, as discussed in detail in Chapter V of this Study.

Most Western Hemisphere kenaf is cut by hand with a bushknife. Almost all of that kenaf is then ribboned, i.e. the bast is stripped off the stalk either manually or by machine, and this must be done while the stalk is still fresh.

3. Kenaf Fiber Production

3.1. Stalk Retting

As for the kenaf agronomy overview, fiber production methods as practiced in Northeast Thailand will here be used as an example as far as South Asian kenaf is concerned.

For the production of textile fiber for sale to bag and hessian mills in Thailand and overseas, the kenaf stalks are transported from the field to wherever water is available, such as swamps, ponds, roadside ditches, rivers, streams, canals and paddy seed beds, into which the stalks are submerged for retting, i.e. the decomposition of the long fiber bearing stalk bark or bast, after which the fiber is stripped from the stalk by hand, washed, dried and field baled; the resulting retted fiber "drums" are then sold by the grower to the local merchant, a baling plant or a bag mill, as the case may be.

Depending upon the distance from the farmer's field to the retting facility, the water availability and the competition for the available water, and similar factors, some 35 to 45 percent of the overall cost/effort is required for the above fiber processing operations, namely the operations subsequent and in addition to the production of field dry whole stalks such as would be required by a whole stalk kenaf pulp mill.

3.2. Ribbon Retting

As stated in the last preceding section on kenaf agronomy, almost all Western Hemisphere kenaf is ribboned after harvesting. This is not because of any basic difference in the "construction" of H. cannabinus and H. sabdariffa stalks, but rather because the former species is mostly produced in regions where there exists neither an abundance of retting facilities, so that these facilities must be specially constructed, nor a labor force willing to undertake the laborious work of manually stripping the retted fiber from the stalk and that under what are considered somewhat noxious conditions. Since, on the one hand, the stripping of the whole bast prior to retting can be done by hand more conveniently or it can be mechanized and, on the other hand, a very much smaller retting facility capacity is required to produce an equal amount of fiber through ribbon retting (as little as 1/24th.) thus reducing investment requirements in retting tank construction as well as water requirements very substantially, such ribbon retting has been adopted almost universally in Latin America, Africa and elsewhere, where kenaf was not previously a traditional crop.

As far as kenaf for paper pulp production is concerned, the ribbon contains the fiber required by a kenaf bast ribbon pulp mill and it would be this ribbon which the mill would desire to purchase from the producers. It is estimated that, based upon the same assumptions as applied to stalk retting in the preceding Subsection 3.1. the peasant farmer would economize from 30 to 35 percent or his cost/effort investment by selling field dry ribbon to the pulp mill rather than field dry retted fiber to the village merchant, bag mill or baling plant.

4. Kenaf Production Methods

The four basic methods under which kenaf textile fiber production is presently organized in various parts of the world are:

Small Holder Operation - Nucleus Farm and Small Holder
Operation - Commercial Plantation Operation - Combined
Small Holder and Commercial Plantation Operation.

Any of these methods could be introduced into new kenaf for paper pulp production areas in the riparian countries and could be adapted to the traditional kenaf production system in Northeast Thailand.

4.1. Small Holder Operation

This is the method in use in Northeast Thailand for the last 25 years, ever since kenaf was first introduced into the region, and for a very much longer period of time in the traditional jute and mesta (kenaf) production areas in India and Bangladesh. Under this production system, the small holder is left very much on his own, with the exception of extension assistance of various and varying degrees of effectiveness and efficiency, and he provides his own inputs and does his own marketing. Under Northeast Thailand conditions, where kenaf has long been the only major cash crop (tapioca is presently becoming a second major such crop), the system worked well - not least due to the resourcefulness and ambitiousness of the Northeast farmers - and, with the incentives a kenaf pulp mill can provide, is confidently expected to generate sufficient raw material not only for the traditional local bag mill and export market but also for possibly two Northeast based pulp mills. Nevertheless, the Northeast farmer could greatly benefit from some centralized assistance and such assistance will probably be required if large scale kenaf production - such as is necessary to assure the substantial raw material requirements of a pulp mill - is to be organized in Laos, Cambodia and Viet-Nam where the peasant farmers are not acquainted with the crop.

4.2. Nucleus Farm and Small Holder Operation

In many developing countries, one of the principal aims of any new agricultural development scheme, such as the kenaf for paper pulp program under discussion, is to raise the standard of living of the peasant farmers. Kenaf production is well suited for this purpose, since it is a cash crop which, in the case of H. cannabinus, requires only 4 to 5 months (6 to 7 months for H. sabdariffa) from seeding to harvesting, it is adaptable to widely varying soil and climatic conditions, and it is not a difficult crop to grow. Nevertheless, it does present production problems for the solution of which the small holder newly introduced to the crop requires outside support, including technical, input, credit and marketing assistance. Under the small holder kenaf production schemes instituted in certain developing countries, such comprehensive assistance services are furnished by "nucleus farms" which may or may not be farmer cooperative supervised or operated. Under the nucleus farm concept, a number of small holders in a certain area planting a total of, say, 500 ha. (1,250 acres; 3,125 rai) minimum to kenaf are grouped around one such farm which supplies the above listed services to growers in its area of coverage, constructs centralized retting facilities, and owns a sufficient number of ribboning machines for renting out to the farmers. In addition, it produces the required amount of selected kenaf seed and advances the cost of land preparation, seed, fertilizer, herbicide, insecticide, ribboning machine operation, and retting tank utilization to the small holder. In fact, the nucleus farm then operates much like a commercial plantation except that, instead of employing and controlling its own labor, it relies upon the labor of the small farmer who is also expected to comply with the instructions of the nucleus farm as far as timing and method of execution of the various production operations are concerned. All service and input cost advances are deducted from the value of the kenaf ribbon or fiber the grower delivers to the nucleus farm at harvest time.

4.3. Commercial Plantation Operation

For the Lower Mekong Basin area, this alternative is mentioned only with respect to the possibility that the kenaf pulp mill may organize its own central farm and limited estate type of production, not so much to grow any significant portion of its raw material requirements, but rather to serve as research and demonstration farm, improved seed production center, extension service station, etc.

The commercial plantation type of production involves the same operations as those described above for the nucleus farm and small holder scheme, except that work is carried out by plantation labor instead of by the peasant farmers and more direct control is exercised. In addition, tractor and equipment services can be scheduled in a more efficient manner since they will not have to be moved from one small peasant farmer plot to the next, and a lesser number of tractors and implements will, therefore, be required. Control over the scheduling and execution of the various operations is entirely in the hands of management and increased yields and efficiency can be expected to result. Total production costs per unit of produce are usually lower than on a peasant farmer production basis (always provided the small holder costs his and his family's labor). Finally, the plantation operation might well be satisfied with a lesser profit than the minimum of net return which would have to be guaranteed to the small holder, after the deduction of all advances payable to the nucleus farm, if he is to be encouraged to go into kenaf production, so that the ultimate sales price to the consumer can be expected to be lower.

4.4. Combined Small Holder and Commercial Plantation Operation

Under this operating alternative, the commercial plantation would, in effect, assume the functions of the nucleus farm. It would produce a limited kenaf crop of its own and organize kenaf production amongst the peasant farmers in the area to whom it would supply the inputs and services listed above as being furnished by the nucleus farm.

Under a future kenaf for paper pulp development scheme in the Lower Mekong Basin area, all four of the above production method alternatives would probably be adopted, with various degrees of interaction and overlap, where it is anticipated that the pulp mills themselves would want to take a leading role in kenaf production promotion in their individual raw material supply areas.

CHAPTER IV - POTENTIAL KENAF PRODUCTION AREAS IN THE LOWER MEKONG BASIN

1. Soil Quality Considerations

In Plate I.1., the potential locations of six kenaf pulp mill sites are indicated, where these sites have been selected principally from the point of view of water and communication facility availability. In this Chapter IV, the potential kenaf production areas to supply possible future pulp mills at any or all of the above potential sites will be discussed.

Plate IV.1. reproduces the official General Soil Map of the Lower Mekong Basin; Annex I contains the descriptive legend for that map. In consultation with the Land Development Department and the Chief Kenaf Officer of the Ministry of Agriculture of the Government of Thailand, a selection was made of the soils on which kenaf can potentially be produced in the Basin area, from the point of view of soil composition, fertility and drainage. In addition, soil quality requirements for H. sabdariffa and H. cannabinus were differentiated, where it was assumed that H. sabdariffa has somewhat lower soil fertility requirements and, because of its root-knot nematode resistance, can be planted on lighter soils but can, of course, also be planted on soils considered suitable for H. cannabinus production. The areas with the selected soils are marked on Plate IV.1., those considered suitable for H. sabdariffa production being colored blue and those considered suitable for H. cannabinus production being colored red, and are listed as follows:

COMMITTEE FOR COORDINATION OF INVESTIGATION
OF THE LOWER MEKONG BASIN

GENERAL SOIL MAP OF THE LOWER MEKONG BASIN

Scale 1:1,500,000

CULTURAL SYMBOLS

- Major town
- +—+—+— Railway
- Main road
- River
- Lake

LEGEND

NOMENCLATURE ACCORDING TO THE FAO/UNESCO SOIL MAP OF THE WORLD

Map Unit	Common Name (Symbol)	Associated Data (Symbol)	Indicators	Texture and Relief
1	Bare Plains (A1)	—	0.00	20
2	Bare Plains (A2)	—	0.00	30
3	Bare Plains (A3)	—	0.00	40
4	Bare Plains (A4)	—	0.00	50
5	Bare Plains (A5)	—	0.00	60
6	Bare Plains (A6)	—	0.00	70
7	Bare Plains (A7)	—	0.00	80
8	Bare Plains (A8)	—	0.00	90
9	Bare Plains (A9)	—	0.00	100
10	Bare Plains (A10)	—	0.00	110
11	Bare Plains (A11)	—	0.00	120
12	Bare Plains (A12)	—	0.00	130
13	Bare Plains (A13)	—	0.00	140
14	Bare Plains (A14)	—	0.00	150
15	Bare Plains (A15)	—	0.00	160
16	Bare Plains (A16)	—	0.00	170
17	Bare Plains (A17)	—	0.00	180
18	Bare Plains (A18)	—	0.00	190
19	Bare Plains (A19)	—	0.00	200
20	Bare Plains (A20)	—	0.00	210
21	Bare Plains (A21)	—	0.00	220
22	Bare Plains (A22)	—	0.00	230
23	Bare Plains (A23)	—	0.00	240
24	Bare Plains (A24)	—	0.00	250
25	Bare Plains (A25)	—	0.00	260
26	Bare Plains (A26)	—	0.00	270
27	Bare Plains (A27)	—	0.00	280
28	Bare Plains (A28)	—	0.00	290
29	Bare Plains (A29)	—	0.00	300
30	Bare Plains (A30)	—	0.00	310
31	Bare Plains (A31)	—	0.00	320
32	Bare Plains (A32)	—	0.00	330
33	Bare Plains (A33)	—	0.00	340
34	Bare Plains (A34)	—	0.00	350
35	Bare Plains (A35)	—	0.00	360
36	Bare Plains (A36)	—	0.00	370
37	Bare Plains (A37)	—	0.00	380
38	Bare Plains (A38)	—	0.00	390
39	Bare Plains (A39)	—	0.00	400
40	Bare Plains (A40)	—	0.00	410
41	Bare Plains (A41)	—	0.00	420
42	Bare Plains (A42)	—	0.00	430
43	Bare Plains (A43)	—	0.00	440
44	Bare Plains (A44)	—	0.00	450
45	Bare Plains (A45)	—	0.00	460
46	Bare Plains (A46)	—	0.00	470
47	Bare Plains (A47)	—	0.00	480
48	Bare Plains (A48)	—	0.00	490
49	Bare Plains (A49)	—	0.00	500
50	Bare Plains (A50)	—	0.00	510
51	Bare Plains (A51)	—	0.00	520
52	Bare Plains (A52)	—	0.00	530
53	Bare Plains (A53)	—	0.00	540
54	Bare Plains (A54)	—	0.00	550
55	Bare Plains (A55)	—	0.00	560
56	Bare Plains (A56)	—	0.00	570
57	Bare Plains (A57)	—	0.00	580
58	Bare Plains (A58)	—	0.00	590
59	Bare Plains (A59)	—	0.00	600
60	Bare Plains (A60)	—	0.00	610
61	Bare Plains (A61)	—	0.00	620
62	Bare Plains (A62)	—	0.00	630
63	Bare Plains (A63)	—	0.00	640
64	Bare Plains (A64)	—	0.00	650
65	Bare Plains (A65)	—	0.00	660
66	Bare Plains (A66)	—	0.00	670
67	Bare Plains (A67)	—	0.00	680
68	Bare Plains (A68)	—	0.00	690
69	Bare Plains (A69)	—	0.00	700
70	Bare Plains (A70)	—	0.00	710
71	Bare Plains (A71)	—	0.00	720
72	Bare Plains (A72)	—	0.00	730
73	Bare Plains (A73)	—	0.00	740
74	Bare Plains (A74)	—	0.00	750
75	Bare Plains (A75)	—	0.00	760
76	Bare Plains (A76)	—	0.00	770
77	Bare Plains (A77)	—	0.00	780
78	Bare Plains (A78)	—	0.00	790
79	Bare Plains (A79)	—	0.00	800
80	Bare Plains (A80)	—	0.00	810
81	Bare Plains (A81)	—	0.00	820
82	Bare Plains (A82)	—	0.00	830
83	Bare Plains (A83)	—	0.00	840
84	Bare Plains (A84)	—	0.00	850
85	Bare Plains (A85)	—	0.00	860
86	Bare Plains (A86)	—	0.00	870
87	Bare Plains (A87)	—	0.00	880
88	Bare Plains (A88)	—	0.00	890
89	Bare Plains (A89)	—	0.00	900
90	Bare Plains (A90)	—	0.00	910
91	Bare Plains (A91)	—	0.00	920
92	Bare Plains (A92)	—	0.00	930
93	Bare Plains (A93)	—	0.00	940
94	Bare Plains (A94)	—	0.00	950
95	Bare Plains (A95)	—	0.00	960
96	Bare Plains (A96)	—	0.00	970
97	Bare Plains (A97)	—	0.00	980
98	Bare Plains (A98)	—	0.00	990
99	Bare Plains (A99)	—	0.00	1000
100	Bare Plains (A100)	—	0.00	1010

KEY TO TEXTURE AND RELIEF

- Coarse texture : less than 10% clay and more than 60% sand
- Medium texture : 10 to 35% clay, or less than 10% clay and more than 65% sand
- Fine texture : more than 35% clay
- Level to gently undulating : constant slopes of 0 to 50 per cent
- Hills to hills : constant slopes of 5 to 30 per cent
- Mountains : constant slopes of more than 30 per cent

* Texture is given 50 cm or 100 cm

THE LINES SHOWN ON THIS MAP DO NOT HAVE OFFICIAL ENDORSEMENT
AS AUTHORITY BY THE UNITED NATIONS

MAP RELIABILITY



- Good reliability based on systematic data
- Fair reliability based on soil survey data
- Poor reliability based on general information

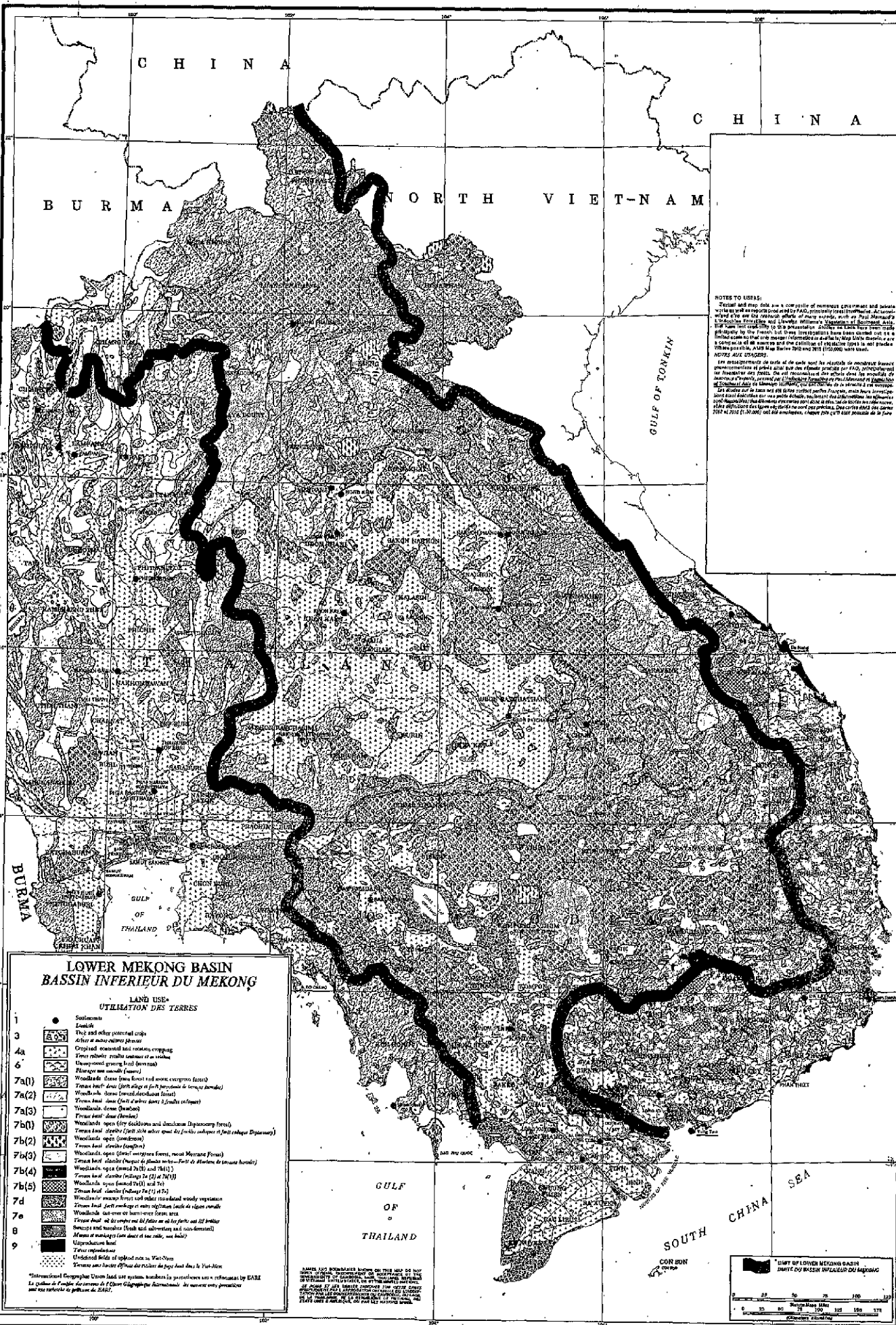
JULY 1972

<u>Map Unit</u>	<u>Dominant Soils</u>	<u>Drainage Rating</u>	<u>Soil Capability</u>
<u>H. sabdariffa</u>			
15	Ferralic Cambisols	Good to Excessive	Moderate to Low
19	Ferric Acrisols, Petric Phase	Good	Moderate but Shallow
<u>H. cannabinus</u>			
16	Gleyic Luvisols	Fair	Good
18	Orthic Acrisols	Good	Moderate
20	Ferric Acrisols	Good	Moderate
23	Dystric Nitosols	Good	Good
24	Orthic Ferralsols	Good	Moderate
25	Rhodic Ferralsols	Good	Good

Upon examining Plate IV.1. and comparing it with the Lower Mekong Basin Land Use Map shown in Plate IV.2., the following tentative general conclusions as to potential kenaf production and supply areas for future pulp and paper production may be reached:

Thailand - Although the dominant soils in most of the Northeast are shown to belong to Map Units 21 and 22, which represent soils typically used for paddy production, large areas of H. sabdariffa are grown in that region. In fact, the blue colored areas in the Northeast coincide with those usually considered to be more fertile and on which, in the past, jute has been grown in the northern sector of the region and successful H. cannabinus tests have been carried out in the western and southern sectors; the same obviously applies to the red colored areas.

Laos - Except for the Vientiane Plain, all other potential kenaf production areas north of the Mekong River should be eliminated, since they are too remote from any of the projected pulp mill sites. On the other hand, there are extensive potential kenaf production areas east of the Mekong River in the Provinces of Khammouane, Savannakhet, Sedone, Champassac and Sithandone.



NOTES TO USERS:

This map and map data are a composite of numerous government and private sources and are not intended to be used for navigation. The map is not a true representation of the actual terrain and is not intended to be used for navigation. The map is not a true representation of the actual terrain and is not intended to be used for navigation.

NOTES AUX USERS:

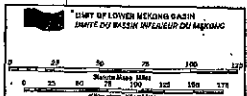
Cette carte et les données de la carte sont le résultat de nombreuses sources gouvernementales et privées et ne sont pas destinées à être utilisées pour la navigation. La carte n'est pas une représentation exacte du terrain réel et n'est pas destinée à être utilisée pour la navigation.

LOWER MEKONG BASIN
BASSIN INFÉRIEUR DU MEKONG

LAND USE
UTILISATION DES TERRES

1	●	Settlements	Localités
3	■	Tree and other perennial crops	Arbres et autres cultures pérennes
4a	■	Cultivated annual and biennial crops	Cultures annuelles et bisannuelles
6	■	Uncultivated grassland (savanna)	Pâturages non cultivés (savane)
7a(1)	■	Woodlands, dense (with forest and some evergreen forest)	Forêts denses (avec forêt et forêt sempervirente)
7a(2)	■	Woodlands, dense (with forest and some evergreen forest)	Forêts denses (avec forêt et forêt sempervirente)
7a(3)	■	Woodlands, dense (with forest and some evergreen forest)	Forêts denses (avec forêt et forêt sempervirente)
7b(1)	■	Woodlands, open (with forest and some evergreen forest)	Forêts ouvertes (avec forêt et forêt sempervirente)
7b(2)	■	Woodlands, open (with forest and some evergreen forest)	Forêts ouvertes (avec forêt et forêt sempervirente)
7b(3)	■	Woodlands, open (with forest and some evergreen forest)	Forêts ouvertes (avec forêt et forêt sempervirente)
7b(4)	■	Woodlands, open (with forest and some evergreen forest)	Forêts ouvertes (avec forêt et forêt sempervirente)
7b(5)	■	Woodlands, open (with forest and some evergreen forest)	Forêts ouvertes (avec forêt et forêt sempervirente)
7d	■	Woodlands, open (with forest and some evergreen forest)	Forêts ouvertes (avec forêt et forêt sempervirente)
8	■	Woodlands, open (with forest and some evergreen forest)	Forêts ouvertes (avec forêt et forêt sempervirente)
9	■	Woodlands, open (with forest and some evergreen forest)	Forêts ouvertes (avec forêt et forêt sempervirente)

*International Geographical Union land use system, modified by permission with reference to EMBL. Le système de l'Union Géographique Internationale, modifié avec l'autorisation de l'EMBL.



Cambodia - Ample potential kenaf production areas exist in an arc around the Great Lake (Tonle Sap) stretching from Takeo in the south through the Provinces of Kompong Speu, Kompong Chhnang, Pursat, Battambang, Siem Reap and Kompong Thom to Kratie in the east; there is also a suitable area in Ratanakiri Province as well as somewhat isolated pockets in Mondulhiri Province.

Viet-Nam - Since the soils in the Delta are unsuitable for kenaf production - and, in any case, the Delta is reserved for food crops - only the Provinces of Kontum, Pleiku and Darlac need be considered in this Study, since they are the only areas of Viet-Nam, apart from the Delta, situated within the Mekong watershed. As will be seen, with the exception of the extreme northern and southern portions, all three provinces are indeed potential kenaf producing areas.

Plate IV.3. then shows a general overview of the potential kenaf supply areas in the Lower Mekong Basin which will be discussed in more detail for each country in the following sections of this Chapter IV.

[illegible][illegible]

[Autonomous municipalities in the Republic of Viet-Nam are underlined]
[Les Municipalités Libres de la République de Viet-Nam sont soulignées]

UNIT OF WATER MEASURING BASIN
LIMITES DU BASSIN INTERIEUR DU MEKONG

0 25 50 75 100 125

0 25 50 75 100 125

30 miles 50 kilometers

Plate IV. 3.

2. Thailand

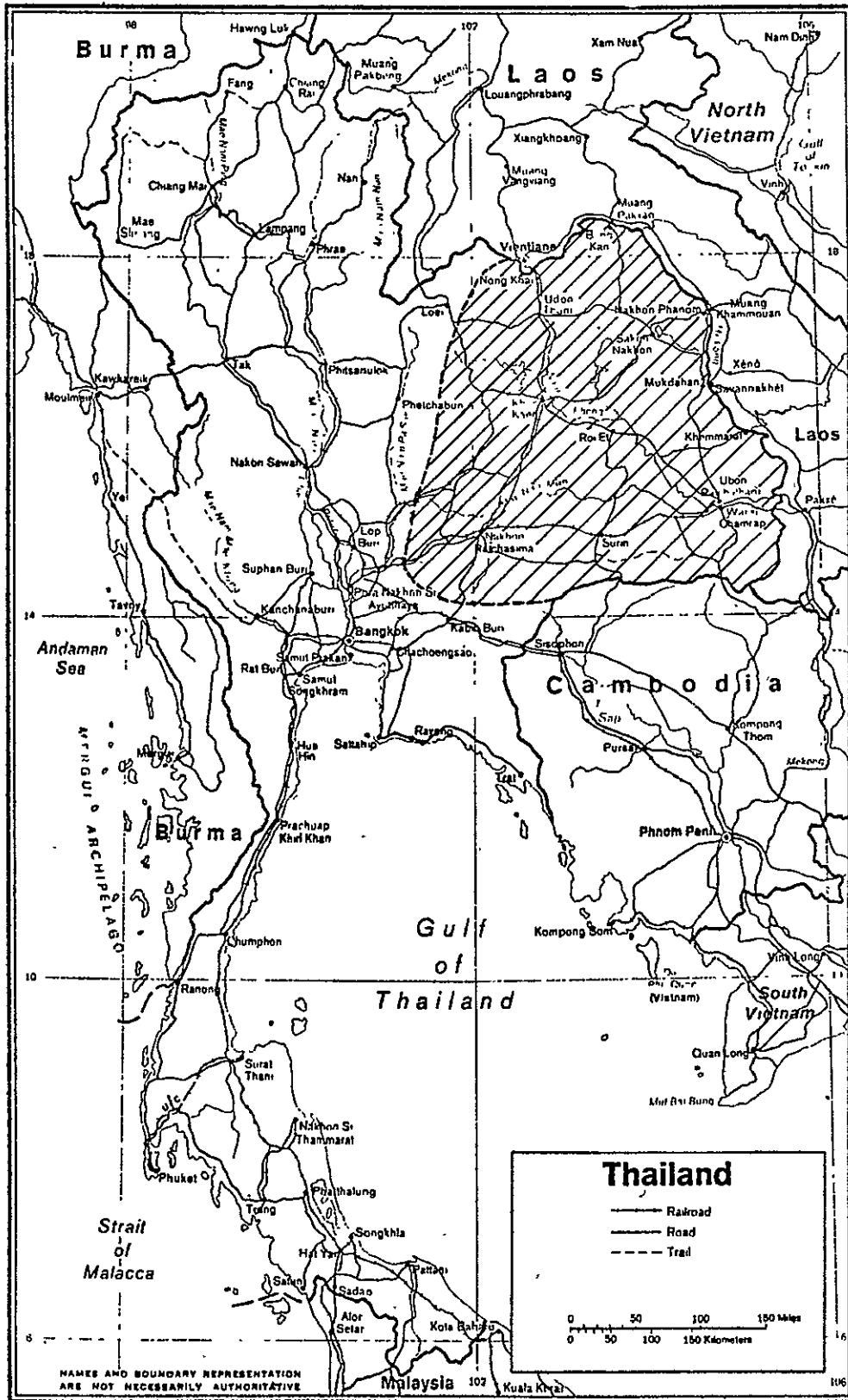
In Thailand, any future kenaf for paper pulp production under riparian country auspices would be limited to the Northeast which is (a) the only part of Thailand located within the Mekong watershed, and (b) the traditional kenaf for textile fiber production area in the country. Furthermore, since Northeast Thailand was the only area within the Lower Mekong Basin freely accessible to the project team at the time of implementation of this Study, the raw material supply situation for a potential future kenaf based pulp and paper industry in the Basin will be discussed using Northeast Thailand as a sample, where Mill Site I and Mill Site II can both be considered for the location of a mill to produce either whole stalk pulp or bast ribbon pulp, as far as raw material supplies (whole stalk kenaf and kenaf bast ribbon respectively) are concerned. Raw material supply programs can then be worked out on the basis of these two examples for the remaining mill sites, once the required Government authorization to visit the respective project areas is granted to a follow-up project team.

As mentioned in Section 1. of this Chapter IV, although the soil map in Plate IV.1. indicates that most of the Northeast comprises gleyic acrisols (Map Units 21 and 22) suitable for paddy production, this obviously refers primarily to the "lowlands" whereas the interspersed "uplands" presumably consist of sandy ferralic cambisols similar to those included in the Map Unit 15 soils but possibly of lesser fertility. As already stated and based purely on field experience rather than on organized research, it appears that the Map Unit 15 and 19 type soils (colored blue in Plate IV.1.) are those on which jute has been grown successfully in the northern sector of the Northeast and H. cannabinus, at least on test plots, in the southern sector of the area, where both are fiber crops requiring better quality soils than H. sabdariffa.

The higher fertility soils (colored red in Plate IV.1.) along the western border of the Northeast, particularly in Changwat Loei, will probably not be used for kenaf in spite of their suitability, since they have traditionally been planted to other crops.

It is then assumed that, in the future as in the past and as shown in Plate IV.4., kenaf production in Thailand, whether for textile fiber and/or for paper pulp, will be concentrated exclusively in the Northeast, that it will be spread all over the Northeast with the exception of Changwat Loei, and that the Map Unit 15 and 19 soils as well as the (limited) Map Unit 18 and 24 higher quality soils can potentially be used for H. cannabinus production and, more particularly, the area around Mukdahan in Nakhon Phanom Province and the southern portions of the Provinces of Nakorn Ratchasima, Buriram, Surin, Sisaket and Ubon Ratchathani.

Potential Kenaf Production Areas
Thailand



3. Laos

Although the Mekong Basin Soil Map (Plate IV.1.) shows suitable potential kenaf production areas in the hilly country north of the Mekong river, these areas are too scattered and too remote from the potential pulp mill sites to be considered as economic raw material supply sources to the mills. However, the Vientiane Plain does lie within the economic bast ribbon supply area of Mill Site I (see Plate IV.5.).

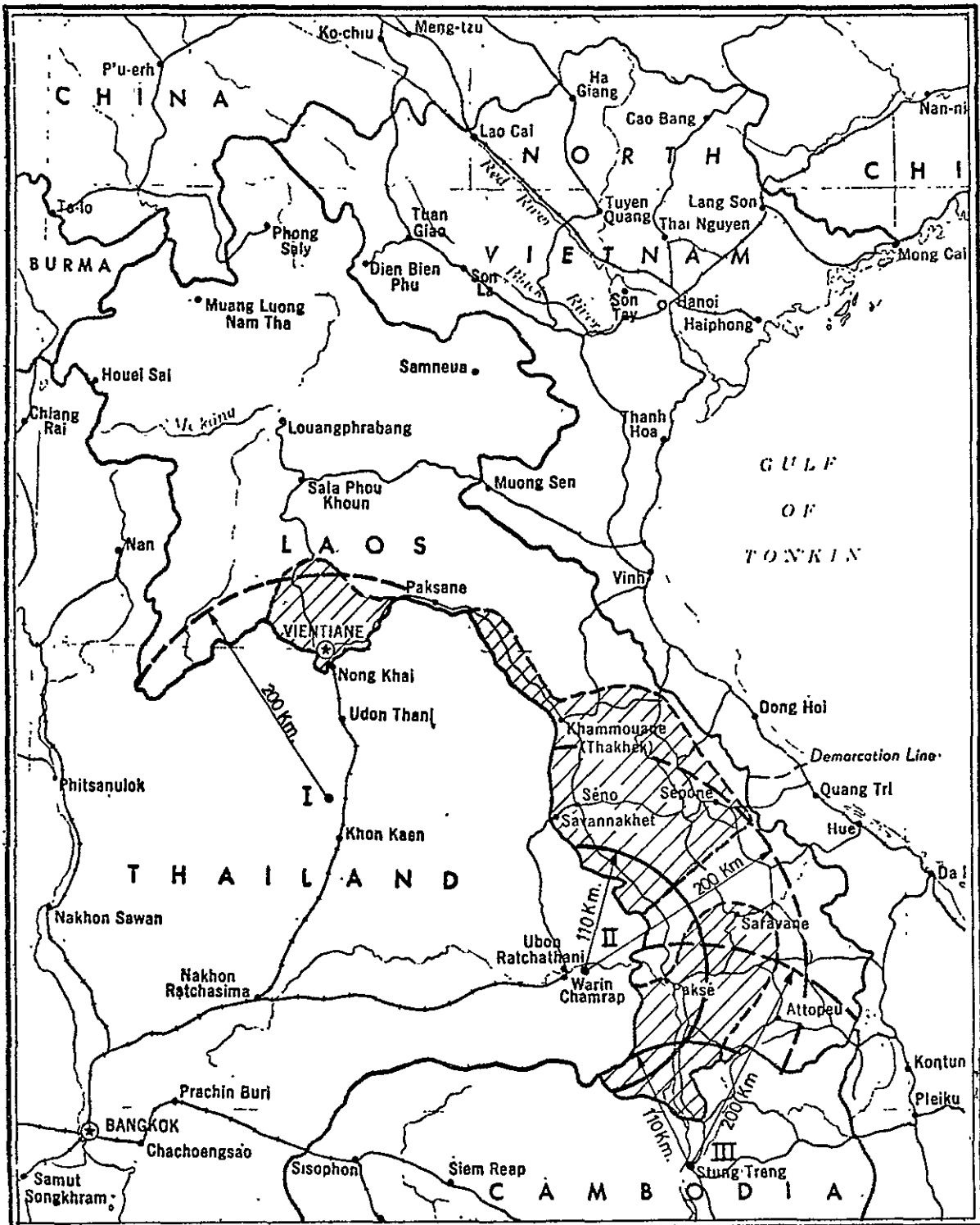
The Mekong Basin Soil Map also shows that there are extensive potential kenaf production areas in the Provinces of Khammouan, Savannakhet, Champassac, Sedone and Sithandone. As shown in Plate IV.5., parts of the Provinces of Savannakhet, Sedone and Sithandone and the entire Province of Champassac lie within a 110 km. radius from Mill Site II near Ubon Ratchathani and, thus, within economic whole stalk transportation distance; similarly, Sithandone Province is included in the whole stalk supply area of Mill Site III at Stung Treng in Cambodia.

With regard to bast ribbon supplies, a reference to Plate IV.5. shows that almost all the potential kenaf production areas in eastern Laos lie within economic supply distance from either Mill Site II and/or Mill Site III, and even the suitable soil areas in those parts of Khammouan Province which lie beyond the 200 km. straight line radius from Mill Sites I and II, are located close enough to these sites to justify including them in the bast ribbon supply area.

In view of the present inaccessibility of the potential kenaf production areas in Laos to the project team, a detailed techno-economic evaluation of kenaf for paper pulp production in the areas shown in Plate IV.5. and the pinpointing of specific optimum production areas will have to be postponed until such time as Government authorization is granted to visit the area. In addition, properly supervised kenaf research must, of course, be carried out before large scale kenaf for paper pulp production is promoted in Laos.

Plate IV.5.

Potential Kenaf Production Areas
Laos



4. Cambodia

Referring again to the Mekong Basin Soil Map (Plate IV.1.), it appears that kenaf could be produced economically in most of Cambodia, except for the hilly coastal region facing the Gulf of Thailand and part of Ratanak Kiri Province (see Plate IV.6.). It also appears that soil and climatic conditions in large parts of Cambodia are favorable for the production of the higher yielding H. cannabinus species of kenaf.

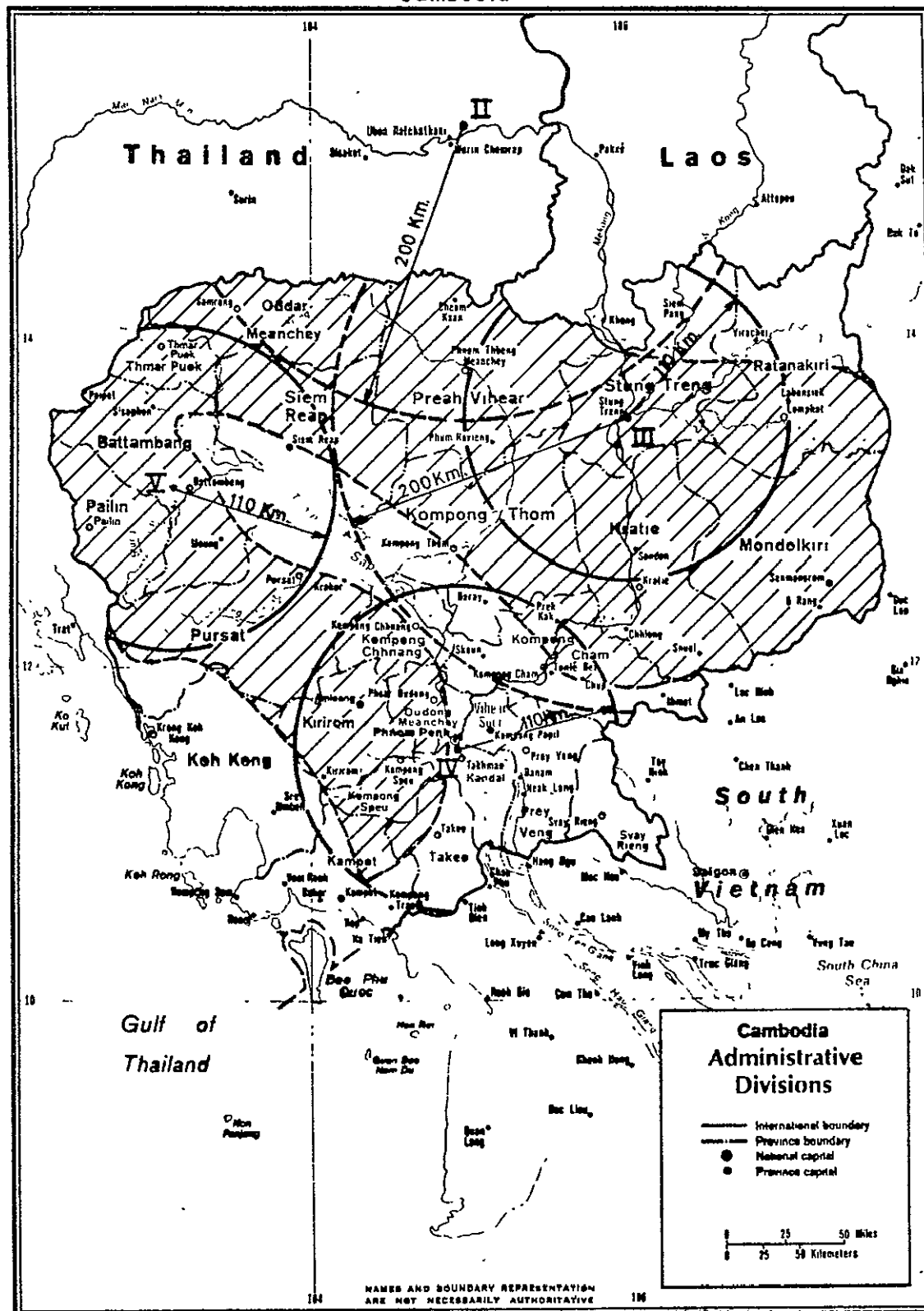
On the basis of physical and soil configuration, the most concentrated substantial kenaf for paper pulp production area in Cambodia would be along the border with Thailand, from the town of Pursat through Battambang to Sisophon and then west to Siem Reap and Stung Treng; potential supplementary supply areas are located within the triangle formed by the towns of Siem Reap, Stung Treng and Kratie, around Lomphat near the border with Pleiku Province in Viet-Nam, and in a band between the hills and the Tonle Sap and Bassac Rivers stretching from Kampong Chhnang through Phnom Penh to Takeo. These areas are located well within economic transportation distance for even whole kenaf stalks to the potential Pulp Mill Sites III, IV and V respectively, and almost any one of them could serve as ribbon supply area for a pulp mill located anywhere in Cambodia, as could the Provinces of Oddar Meanchey, Prear Vihear and Stung Treng with respect to a pulp mill located near Ubon in Thailand.

Plate IV.7. in the next Sub-Section IV.5. shows that the potential kenaf production areas in the eastern part of Cambodia would also lie within the kenaf raw material supply area of a pulp mill established at Mill Site VI near Ban Me Thuot in Viet-Nam.

A general outline of the potential kenaf for paper pulp production areas in Cambodia will be as shown in Plate IV.6.

Again, organized kenaf research trials would have to be implemented in Cambodia before large scale production of the crop is promoted amongst the small holders.

Potential Kenaf Production Areas
Cambodia



5. Viet-Nam

Only two areas of Viet-Nam - the Delta and the Central Highland Provinces of Kontum, Pleiku and Darlac - are located within the Lower Mekong Basin. The soils in the Delta, as shown in the map on Plate IV.1., are unsuitable for kenaf production and, at any rate, the Delta will probably continue to be reserved mainly for food crop production. With regard to the Central Highlands, it will be seen that all three Mekong Basin provinces contain suitable areas for kenaf production, although limited by the hilly nature of the terrain, particularly in the extreme north and south of the area. Kenaf has, in fact, been grown successfully in these Highland provinces in the past. Plate IV.7. outlines these potential kenaf for paper pulp production areas.

In Chapter I, Section 6, mention has been made of a potential Kenaf Pulp Mill Site VI near Ban Me Thuot in Darlac Province. Consideration of that site has been included only so as to provide a possible mill site in Viet-Nam within the Mekong Basin area. It seems obvious that, in actual fact, any future kenaf pulp mill in Viet-Nam would be sited at a more central location and one with better communication facilities than Ban Me Thout. Nevertheless, Plate IV.7. shows that a pulp mill even at Site VI would be well situated as far as raw material supplies are concerned in that a circle with a 110 km. straight line radius from the mill site (whole stalk supply area) includes the Provinces of Darlac, Pleiku, Then Duc and Quang Duc in Viet-Nam, all previous kenaf producing provinces, as well as part of Mondolkiri and Ratanak Kiri Provinces in Cambodia, and a circle with a 200 km. straight line radius from the mill site (bast ribbon supply area) additionally covers the former kenaf producing Vietnamese Provinces of Kontum, Long Khanh, Binh Long and Phuoc Long, as well as the Cambodian Province of Kratie.

South Vietnam

- International boundary
- Province boundary
- National capital
- Province capital
- Autonomous municipality
- Railroad
- Road
- Trail

0 25 50 75 Miles
0 25 50 75 Kilometers

Names and boundary representation are not necessarily authoritative.

CHAPTER V - KENAF PRODUCTION FOR PAPER PULP

1. Kenaf Stalk Composition

As discussed elsewhere in this Study (Chapter I, Section 3), kenaf stalks contain two distinctly different types of fiber. The long bast fibers are located in the outer bark portion of the stem, whereas the shorter woody fibers are in the thick inner core. The average length of the bast fibers is approximately 2.5 millimeters, and that of the woody core fibers is 0.5 to 0.6 millimeters.

The top leafy part of the kenaf plant has less value for pulping and should be removed and either returned to the ground as fertilizer or collected and used for feed. When the stalks are harvested by hand, a tractor-drawn cutter bar or other simple mechanical equipment, as is the case in the developing countries, the manual topping of the harvested stalks presents no problem. Alternatively, the stalks can be shocked in the field for a few days which will cause the leaves (but not the underdeveloped top portion of the stalk and any seed capsules) to drop off. The same defoliation will be achieved if the stalks are left standing uncut in the field for a considerable period beyond maturity.

For whole stalk pulping in the high labor cost industrialized countries, such as the United States where forage choppers have been employed up to now for kenaf stalk harvesting, high-stalk topping attachments will have to be perfected and employed in green stalk harvesting; in the field dried (uncut overmature) crop, most of the leaves drop off as a result of natural dessication or after being killed chemically or by frost.

Extensive tests have been carried out on the composition of H. cannabinus kenaf stalks, particularly as part of the ongoing kenaf for paper pulp development program in the United States but also elsewhere. One set of composite averages assembled during the kenaf development program in Viet-Nam (Chapter II, Section 4) showed the following stalk fraction weights and composition:

Green kenaf plants	1,000.00 kg.	
Dry core (woody stem)	130.80 kg.	46.7%
Dry bast ribbon	80.54 kg.	28.7%
Dry leaves	68.54 kg.	24.6%
Total dry weight	279.88 kg.	100.0%
	=====	=====

(Note: Moisture Content of Green Stalks = 72.0%)

As stated, the leaves have no value for paper pulp manufacture and are discarded. Total dry core and bast ribbon weights amounted to 130.80 kg. plus 80.54 kg. = 211.34 kg. and the stalk fraction ratio was:

Core	= 62%
Bast Ribbon	= 38%

The results of much more detailed tests carried out at various locations in the United States are shown in Table V.1. According to that table, the bast fiber length averaged 2.54 mm. and the core fiber length averaged 0.56 mm.; the total core plus bast ribbon maceration yield from the stalk averaged 32.28 percent for the core material and 19.88 percent for the bast ribbon; and the stalk fraction ratio was:

Core	= 62%
Bast Ribbon	= 38%

Subsequent tests in 1972 and thereafter showed an average stalk fraction ratio of:

Core	= 60%
Bast Ribbon	= 40%

by weight, on an oven dry basis.

In Sections 3.2.1. and 3.2.2. of this Chapter V, the kenaf whole stalk yield ranges per unit area have been estimated for H. sabdariffa and H. cannabinus respectively; in Section 5.2., actual bast ribbon yield ranges for H. cannabinus are indicated based upon the Consultants' extensive experience in kenaf for textile fiber production, and the bast ribbon yield ranges for H. sabdariffa are deduced therefrom. It will be seen that these various yield ranges are as follows, all on a field dry (FD = 12.5 percent moisture content) basis:

Fiber Dimensional Characteristics and Maceration Yield
of Green and Field Dried Kenaf

Material Tested and Location	Crop Year	Fiber Length		Fiber Width		Maceration Yield	
		Bast	Woody Core	Bast	Woody Core	Bast	Woody Core
		Millimeters	Millimeters	Microns	Microns	Percent	Percent
Green Kenaf:							
Gainesville, Fla.....	1965	2.42	0.45	17.0	33.6	26.2	32.7
Peoria, Ill.....	1965	2.32	.48	15.7	30.1	22.5	34.0
Do.....	1966	2.25	.51	18.4	34.5	18.0	28.9
Do.....	1967	2.91	.68	17.5	34.4	19.8	27.6
Urbana, Ill.....	1957	2.78	.49	19.2	37.9	25.2	29.7
St. Gabriel, La.....	1967	2.70	.62	15.7	32.4	13.3	30.3
College Station, Tex.....	1965	2.66	.74	16.9	25.6	15.6	41.2
Field-Dried Kenaf:							
Experiment, Ga.....	1964	2.80	.61	14.6	33.3	20.5	29.3
Peoria, Ill.....	1965	2.52	.51	15.9	30.7	19.8	36.6
Do.....	1966	2.28	.45	17.5	42.3	21.1	30.2
Do.....	1967	2.26	.53	18.9	37.4	20.4	30.7
Urbana, Ill.....	1959	2.34	.63	17.6	29.6	15.0	33.0
Columbia, Mo.....	1958	2.81	.57	15.8	31.2	21.0	35.4
Reference Materials:							
Softwoods.....		2.9-6.3		22-36	
Southeastern Slashpine.....		3.1-5.4		40-58	
Hardwoods.....		.85-1.8	
Espartograss.....		.99-2.10		9.7-11.8	
Bamboo.....		1.36-4.0		8.7-22.0	
Sugarcane Bagasse.....		1.7		20.0	

Table V.1.

	<u>H. sabdariffa</u>	<u>H. cannabinus</u>
Whole stalk yield (FDMT/ha.)	7.500 to 9.375	15.000 to 20.000
Bast ribbon yield (FDMT/ha.)	1.80 to 2.25	3.60 to 4.80

Based upon the above indicated whole stalk and bast ribbon yield ranges, the bast ribbon represents 24 percent, by weight, of the whole stalk. This is a rather lower percentage figure than is generally assumed; nevertheless, the Consultants maintain that, since their bast ribbon yield figures are based upon some 30 years of field experience with such ribbon production in the developing countries and represent ribbon yields obtainable in actual commercial field operations, it would be unrealistic to assume higher yield figures than those indicated above.

Additional stalk composition tests will, obviously, have to be undertaken in any projected kenaf for paper pulp production area in the riparian countries or elsewhere since, as Table V.1. clearly shows, the bast to core ratio varies substantially according to the location, in other words according to soil and climate conditions. Based upon the Consultants' experience with kenaf textile fiber production, other variables affecting this ratio are planting date, stalk age and size at harvest, etc.

2. Kenaf Production Agronomics

2.1. Land Clearing and Preparation

The manner and thoroughness of land clearing will depend upon the type of operation involved - individual small holders, nucleus farm assisted small holders or cooperatives, commercial plantation - and the vegetation to be removed. Ideally, the land should be completely cleared and stumped to permit subsequent mechanized or, at least, semi-mechanized operations, but this may not always be feasible or economic for the independent small holder, particularly in heavily wooded areas. However, reductions in yield and production efficiency must then be accepted. In large-scale operations, complete land clearing is essential including, if necessary, bulldozing, ripping, some plowing, etc.

In view of the small size of kenaf seed, particularly of that of H. sabdariffa, the soil must be thoroughly broken up before planting if good seed germination and initial seedling growth are to be achieved. The land preparation methods traditionally used by the kenaf farmer in Northeast Thailand have already been described in Chapter III, Section 2.1. Similar methods would, most likely, be adopted in any additional H. sabdariffa production areas where similar light, sandy upland soil conditions prevail for which the shallow penetrating wooden plows and rakes have proven themselves adequate. For heavier soils, deeper plowing and harrowing will be necessary, preferably by tractor-drawn implements. Under such mechanized system, land preparation normally consists of one plowing and cross-plowing followed by harrowing and cross-harrowing and another harrowing immediately prior to seeding in order to prepare a fine tilth seed bed and to kill any weeds that may have germinated after the initial harrowing. This latter is particularly important in the case of Western Hemisphere kenaf (H. cannabinus) plantings, where no weeding is done subsequent to seeding and where, if the weeds have a headstart, they may outgrow the kenaf seedlings and the field may have to be abandoned or replanted.

2.2. Seed Varieties

2.2.1. South Asian Kenaf

In the traditional H. sabdariffa production areas in Northeast Thailand, the peasant farmers will continue to plant the standard Thai Red and Thai Green varieties utilizing mostly their own seed collected from the previous year's plantings. As the Thai Government sponsored improved seed production program gathers momentum, such superior quality seed will progressively replace the farmers' homegrown seed which should lead to a substantial increase in stalk (and ribbon) yields.

Extensive nursery tests have already been carried out in Thailand with a number of H. sabdariffa varieties introduced from Indonesia and yields materially exceeding those of the local varieties have been achieved. The best selections are stated to be THS-30 and THS-44. The apparent superiority of the Indonesian varieties is confirmed by the experimental work in Viet-Nam (Chapter II, Section 4), where the THS-22, THS-24 and THS-30 selections have provided the best results. Hence, those varieties should gradually be introduced in Northeast Thailand and should preferably be used exclusively for any South Asian kenaf for paper pulp plantings in Cambodia, Laos and Viet-Nam.

2.2.2. Western Hemisphere Kenaf

As pointed out under the Western Hemisphere Kenaf Agronomy section in Chapter III, a range of H. cannabinus varieties is available offering substantial flexibility as far as planting and harvesting periods at different latitudes are concerned. Recent experience in the tropics and sub-tropics has shown that, overall, the two photo-insensitive Guatemalan varieties, G-4 and G-45, generally produce the highest bast ribbon and retted fiber yields, and that they are closely matched by the more photo-sensitive Cuban C-2032 variety at latitudes beyond 15 degrees north and south of the Equator. In the absence of evidence to the contrary, it is assumed that they will also produce the best whole stalk yields.

The only available detailed records of H. cannabinus test plantings in South Asia are those summarized in Chapter II, Section 4., for Viet-Nam during the 1957 to 1962 period. Unfortunately, the

varieties listed by numbers and letters in Table II.4. could not be further identified, but it is assumed that Variety 2A is one of the photo-sensitive Cuban varieties and that the four photo-insensitive varieties originated from the then ongoing Guatemalan program which emphasized the selection of such "late maturing" varieties.

The Everglades 41 and Everglades 71 varieties listed in the table were developed in Florida and have given excellent yields in the U.S. kenaf for paper pulp program, as at least the Everglades 71 variety appears to have done also in Viet-Nam, and they should be included in any future kenaf for paper pulp research program in the Lower Mekong Basin area which should thus comprise the following H. cannabinus varieties:

Cuba 2032
Guatemala 4
Guatemala 45
Everglades 41
Everglades 71

2.3. Planting

2.3.1. Planting Periods

In the Lower Mekong Basin area, the start of the kenaf planting period will have to coincide with the onset of the rains since it must be excluded that irrigation facilities are made available for the crop, such facilities being reserved for essential food crop production. On the average, the rainy season in the riparian countries starts in April/May and, for purposes of this Study, May 15 will be assumed to be the starting date for the planting of the kenaf for paper pulp crop.

In order to achieve maximum yields, the photo-sensitive varieties must be planted as early as possible so as to permit optimum stalk development prior to flowering at which time the vegetative growth of the plant is arrested. Amongst these varieties are included all the H. sabdariffa varieties as well as the Cuba-2032 and the two Everglades varieties of H. cannabinus. The planting date of all of these varieties should not extend beyond June 30 at the most.

The photo-insensitive varieties (Guatemala 4 and 45) in theory flower about 125 days from planting, independent of the date of planting and of the length of daylight. However, they are not entirely photo-insensitive; they have also been observed to continue developing vegetatively after flowering. Hence, although on-the-spot tests will have to be made with these varieties to determine optimum planting periods for each location, it can be assumed that they will permit much greater flexibility, including staggered planting and, therefore, staggered harvesting at the optimum stage of maturity, which could be of significant economic importance to the pulp mill.

2.3.2. Planting Methods

Most of the kenaf produced for any future pulp mill development program in the Lower Mekong Basin will be grown by peasant farmers who will plant the crop employing the methods already well established in Northeast Thailand and including the more recently introduced improvements. Such planting methods will definitely comprise row-planting (rather than broadcast or hill planting) and that preferably with the help of the draft animal pulled six-row seed rake previously developed for use in both Viet-Nam and Thailand. Parallel shallow

(2.5 cm. deep) rows will be opened in the prepared seed bed with the seed rake, the seed will be dibbled into the rows by hand at a rate of approximately 12.5 kg./ha. for H. sabdariffa and 25 kg./ha. for H. cannabinus, and either the reversed seed rake or a log will be pulled over the field to close up the rows. In view of the necessity of weeding and thinning the H. sabdariffa plantings, the rows for that species will be planted 30 cm. apart and the seedlings will later be thinned to 8 to 10 cm. between plants in the row. For H. cannabinus, the inter-row spacing will be 17 to 20 cm.

On any commercial type kenaf plantation operation (e.g. on pulp mill sponsored central and/or demonstration farms) or when the kenaf is planted with nucleus farm assistance, the seed may well be planted with the help of tractor-drawn seed drills. The standard grain drills have performed satisfactorily in the past, but it is understood that new types, such as the flexiplanters, provide superior performance. The drill should be set to give shallow (1.5 to 2.5 cm.) placement and this depth of planting should be carefully controlled. It should also be ascertained that the drill drops the seed uniformly and at the recommended rate.

On the subject of the all-important inter-row planting distances and seeding rates for optimum kenaf yield results for pulping purposes, the published United States test results appear to have little application to Lower Mekong Basin conditions, and the agronomics of kenaf for paper pulp do not seem to have been studied anywhere in the developing countries of the tropics so far. Under the United States program, climatic conditions most closely approximating - but by no means meeting - the more favorable kenaf production conditions in the tropics were encountered in Florida and Texas, but even there kenaf production was limited by frost and the crop had to be planted in raised beds in some locations to avoid water logging. Also, any United States kenaf for paper pulp production must be completely mechanized to be economically feasible; this requires wide row spacing so as to permit harvesting with the available forage harvester/chopper equipment and most tests compare results from 48 cm. (19 in.) and 96 cm. (38 in.) inter-row spacings, whereas large-scale commercial H. cannabinus plantations (for fiber) in the tropics are usually planted at 17.5 cm. (7 in.) to 20 cm. (8 in.) inter-row distances.

On the other hand, optimum kenaf stalk yields appear to have been obtained in the United States program with final plant populations of 190,000 to 250,000 plants per hectare (75,000 to 100,000 plants/acre) at harvest time, and the identical final plant population is aimed at in the standard tropical kenaf fiber plantings. At some 45,000 seeds

per kilogram and 80 percent germination, the U.S. technicians then suggest a 6.8 to 9.1 kg./ha. seeding rate. In the standard tropical kenaf (for fiber) plantations, a 25 kg./ha. seeding rate is usually employed to provide for irregularities in planting and germination; the plants then thin themselves out through inter-plant competition to an approximate final population of 250,000 plants per hectare and an approximate plant-to-plant spacing in the row of 8 to 10 cm.

Whereas the above "precision" seeding method is probably well applicable to the United States, it is suggested that the "traditional" heavier seeding rate be employed in the tropics, and it is recommended to plant by seed drill, at 17.5 cm. (7 in.) between the rows and at the rate of 25 kg. of seed per hectare (22 lbs./acre).

2.4. Types and Quantities of Fertilizer and their Application

2.4.1. South Asian Kenaf

The application of chemical fertilizers is not very widespread on the kenaf farms in Northeast Thailand, the only major South Asian kenaf production area in the riparian countries. Most kenaf farmers simply do not have the money to buy fertilizer and credit facilities for its purchase are still scarce. Furthermore, the financial return from the use of fertilizers was not very attractive at the farm level prices for retted kenaf fiber prevailing in the Northeast until recently.

The rate of application of 12:24:12 fertilizer recommended by the Thai Ministry of Agriculture is 40 kg./rai (250 kg./ha.). At $\text{฿}3.80/\text{kg.}$, the present Thai Government regulated price, total fertilizer costs are then $\text{฿}152/\text{rai}$ ($\$47.50/\text{ha.}$). The average increase in retted fiber yield through fertilizer application that can reasonably be expected under Northeast Thailand conditions is about 25 percent. Present average yields, without the use of fertilizer, being about 184 kg./rai (1,150 kg./ha.), about 230 kg./rai (1,437.5 kg./ha.) could be produced if fertilizer is applied, no other improved planting, cultivation or processing methods being used. Hence, these 46 kg./rai of increased fiber production must pay the cost of the fertilizer and its application and must show a sufficiently large profit to justify the additional risk and effort incurred. At $\text{฿}152/\text{rai}$ fertilizer cost, the farm gate price of retted fiber must then be at least $\text{฿}3.30/\text{kg.}$, not taking transportation and labor costs into account, a price level which has only rarely been achieved even during the most recent five-year period when price averages tended to be higher than previously.

As an alternative to the above fertilizer compound and rate of application, the Thai Department of Agriculture recommends the application of 50 kg./rai (312.5 kg./ha.) of 8:16:8 or 100 kg./rai (625 kg./ha.) of 4:8:4 fertilizer under most Northeast soil conditions, and H. sabdariffa would probably largely be grown under similar soil conditions also in the other riparian countries. The Department further comments as follows:

- The application of ammonium sulphate as a nitrogen fertilizer produced somewhat higher yields than the application of urea;

- Kenaf plants receiving fertilizer at various rates showed greatly improved development in the initial stages. At harvest time, heavily fertilized plants showed substantially greater vegetative development, but the fiber content did not increase in proportion to the rate of increase in fertilizer application;
- When phosphorus is the principal limiting factor of the soil (analysis value of available P less than 10 ppm.), P should be applied at a moderate rate (8 to 12 kg./rai = 50 to 75 kg./ha. of P₂O₅). When the soils show an available P value of around 13 ppm. or more, no phosphorus fertilization is required;
- Nitrogen should be applied as a starter at the rate of 4 to 8 kg./rai (25 to 50 kg./ha.) of ammonium sulphate;
- With soil analysis values of 1.2% of O.M. and 14.9 ppm. of available P, H. sabdariffa shows very little response in yield to nitrogen or phosphorus fertilization and any fertilizer applied on this soil type, one of the typical soils predominating in the Northeast, would be wasted.

Table V 2. summarizes the experimental fiber yield data obtained at various levels of nitrogen and phosphorus application in Northeast Thailand.

In the Northeast, chemical fertilizer is commonly applied in two equal doses: one-half as a side dressing immediately after the first weeding, some 30 days after germination, and the other half as a top dressing after the second weeding, some 60 days after germination. For the first application, a shallow furrow is opened with the hoe next to the row of kenaf plants, and the fertilizer is dropped by hand into the furrow which is then closed with the foot and the soil tamped down. Thirty days later, the second half of the fertilizer is applied by spreading it by hand between the rows and turning it into the soil with the hoe. No fertilizer is generally applied prior to planting or at the time of planting, the farmers fearing that the heavy rains at the start of the rainy season will leach the fertilizer out of the sandy soil before the seedlings can profit from it.

As discussed in Chapter II, Section 4.1., the 1957 to 1962 research program in Viet-Nam resulted in a fertilizer recommendation, for H. sabdariffa, of 60-30-120 as kilograms of N-P₂O₅-K₂O per hectare (9.6-4.8-19.2 kg./rai). As will be seen, this recommendation differs substantially from that put forward by the Thai Ministry of Agriculture for Northeast Thailand doubtlessly due, in part, to the different soil

Summarized Data on Retted Fiber Yield of H. Sabdariffa as Affected by Various Levels of Nitrogen and Phosphorus, Northeast Thailand

Location	Nitrogen (kg./rai)				Phosphorus (kg./rai)			
	0	4	8	16	0	8	16	24
	Yield (kg./rai)							
Amphur Muang, Chaiyaphum	480.1	506.1	520.9	514.9	493.3	493.7	521.1	513.7
Chaturas, Chaiyaphum	528.9	539.9	557.6	492.5	500.3	543.9	520.1	554.5
Borabu, Mahasarakam	401.7	449.5	469.2	412.7	300.1	469.5	487.0	476.5
N.E. Agric. Research Center	370.8	467.6	366.4	395.0	352.6	377.0	397.2	376.2

Note: 1 Kg./Rai = 6.25 Kg./Ha.

conditions under which the crop was grown in Viet-Nam. Nevertheless, it is obvious that additional fertilizer trials are required to enable authoritative fertilizer recommendations to be made for each specific South Asian kenaf production area.

2.4.2. Western Hemisphere Kenaf

Experience in all kenaf production areas in the developing countries shows that H. cannabinus responds strongly to fertilizer application on any soil, particularly to nitrogen. Since no large scale fertilizer experiments have, so far, been carried out in the riparian countries (except for Viet-Nam as discussed below), tentative recommendations can only be based on experience elsewhere, subject to detailed tests in each proposed production area. An initial fertilization program might then consist of the application of 135 kg./ha. (21.6 kg./rai) of urea (46% N) and of the same quantity of, say, 15:15:15 composite formula, equivalent to 92 kg. N, 30 kg. P and 30 kg. K per hectare (14.72-4.8-4.8 kg. NPK per rai).

Again, the 1957 to 1962 research program in Viet-Nam differs materially from the above in its fertilizer recommendations, particularly with regard to nitrogen, and suggests an optimum application rate of 60-30-60 as kilograms of N-P₂O₅-K₂O per hectare. Although the validity of these recommendations under Viet-Nam research site soil conditions is not doubted, the wide variation on recommended fertilizer applications does emphasize the need for further trials in each specific proposed H. cannabinus planting area.

Since Western Hemisphere kenaf will be planted at 17 to 20 cm. (7 to 8 in.) inter-row spacings, i.e. much closer than South Asian kenaf, and since its seedlings grow at a much faster rate, side and top dressing of fertilizer, as used for H. sabdariffa production, will be impractical. Instead, the fertilizer will be applied prior to and/or at the time of planting.

The simplest way is either to spread the fertilizer by hand and turn it into the soil with the hoe, or to open a row with a stick, dibble the fertilizer into the resulting furrow, and close the furrow with the foot. A more efficient method is to open shallow furrows with a multi-row wooden rake, spread the fertilizer into the furrows by hand, and then again draw the rake through the furrows to mix the fertilizer into the soil. Another method is to apply the fertilizer using a single-row hand-pushed fertilizer drill.

In large commercial type operations or on peasant farmer plots serviced by a central or nucleus farm, the fertilizer should be applied at the time of planting using a tractor drawn seed drill with a fertilizer box. Fertilizer application by spreader prior to planting involves an additional operation and offers no particular advantage and is, therefore, not generally recommended.

2.5. Cultivation

2.5.1. South Asian Kenaf

The major inter-cultural operations in H. sabdariffa production are weeding, thinning and replanting.

Weeding must be carried out at the proper time and intervals, if high yields are to be obtained. If the weeds are not kept in check, they will not only take valuable soil nutrients away from the kenaf plants, but they will also shade out the young seedlings and stunt their growth. The first weeding should be done about one month after germination and the second weeding one month later. Normally, no further weeding will be required, since the plants will then be tall and leafy enough to shade out the weeds. Since weeding is a time and labor consuming operation, it is often neglected; it is specially laborious in broadcast sown fields and in fields where the crop has been hill planted without placing the hills in rows.

In broadcast planted fields, a tubular-type instrument or "spade" must be used for weeding, since the regular hoe is too wide for the irregular and often narrow distances between the individual plants. Weeding is facilitated considerably in row planted kenaf. The space between the rows can be hoed rapidly and this manual operation can also be replaced by weeding with a hand pushed wheel hoe.

In order to obtain tall and healthy plants of adequate stalk diameter, each plant must have sufficient room to grow. The superfluous plants are removed by "thinning", an operation which should be carried out immediately after the first weeding. Optimum distance between plants is 5 to 7 cm. (2 to 3 in.). If the kenaf has been planted in hills, only two or three plants should be allowed to grow and the rest should be pulled out. The distance between the remaining seedlings should be no less than 5 cm.

If the kenaf has been row planted in furrows, thinning becomes an easy operation. Enough young plants are pulled out so that the distance between the remaining seedlings in the row becomes 5 to 7 cm. or the width of three or four fingers; obviously, the weak rather than the stronger seedlings are removed.

Some farmers use the stronger seedlings pulled out during thinning to replant the "misses" in their kenaf or those parts of the

field where the seed may have germinated unevenly or not at all. Shallow holes are dug with a hoe in line in the ground, two seedlings are placed into each hole by their roots, and the soil is pushed with the foot over the roots and tamped down firmly. Replanting will be successful only when the soil is already moist and if the area is promptly watered or if it rains soon after the operation.

2.5.2. Western Hemisphere Kenaf

None of the above three inter-cultural operations - weeding, thinning and replanting - are required or are applicable to H. cannabinus production if the crop is planted in rows 17 to 20 cm. (7 to 8 in.) apart as recommended. The shading effect of the palmate leaves of the fast growing seedlings will suppress the weeds and will also kill the weaker slower growing seedlings. This is, of course, a major advantage of H. cannabinus over H. sabdariffa production, as it eliminates two of the most costly and labor intensive operations.

Replanting in the closely seeded H. cannabinus rows is impractical and only fairly extensive areas should be considered for such operation, and that from seed rather than seedlings.

2.6. Pests and Diseases and their Control

Although both South Asian and Western Hemisphere kenaf are remarkably resistant to pests and diseases, these do of course occur and are likely to increase as a result of frequent and intensive kenaf production.

- Insect Pests

Kenaf is attacked by a number of insect species around the world some of which may become destructive in certain areas unless controlled. The species of importance include:

The small black flea beetle of the family Chrysomelidae attacks the stem and leaves of kenaf, usually in the later stages of growth. The insect has been noted in Thailand and Viet-Nam as well as in Indonesia, New Guinea and Africa. Control measures include early harvest of infested areas or spraying with the equivalent of 10 kg./ha. of 5 percent DDT. This will also control a secondary pest, the leaf hopper of the family Cicadellidae.

The European corn borer, Pyrausta nubilalis H., sometimes damages kenaf in areas where corn is the predominant crop. Control can be achieved by planting corn as a trap around the kenaf to attract the borer and then harvesting and burning the residue.

The cotton stainer, Dysdercus saturnellus, may attack the seed capsules of kenaf and thus destroy the seed crop. It may be controlled by spray applications of Dieldrin at weekly intervals using the equivalent of 0.5 kg. of 100 percent active ingredient per hectare.

The larvae of Anomis sp. and the Southern Army Worm, Prodenia eradiana, may defoliate the kenaf. Control of both may be effected by the use of 10 percent Toxaphene dust.

Aphis gossypii Glov., the cotton aphid, sometimes infests young kenaf and may be controlled by spraying with the equivalent of 1 to 2 kg./ha. of Malathion.

Agrotis ypsilon Rott., the black cutworm, and Feltia subterranea Fab., the granulate cutworm, have damaged stands of young kenaf, cutting the plants off near the soil level. The best control is good land preparation well in advance of planting and application of Toxaphene at the rate of 1 to 2 kg./ha.

- Diseases

The most serious diseases attacking kenaf are largely fungal in nature and most of them are seed or soil borne. Control measures consist of selection of disease resistant varieties, seed treatment with organic or mercurial fungicides, and early harvest of affected areas. Major diseases of kenaf include:

Colletotrichum hibisci Poll., sometimes called anthracnose or tip blight, at one time was one of the most destructive diseases of kenaf, specially of H. cannabinus. This disease is characterized by apical stem swelling, stem and leaf lesions and curling or distortion of both in the early stages. However, the better known kenaf varieties have been selected for anthracnose resistance and furnish adequate control.

One of the major kenaf diseases is a soil borne fungus, Phytophthora parasitica Dast. It is characterized initially by wilting of the plants in the middle of the day with apparent recovery at night, but eventually the wilt becomes permanent. Examination will disclose rotting of the root system which possesses a reddish color. The disease gradually extends 15 cm. or more from the soil level up the stem. It may occur at any stage of plant development if the growing conditions are poor but usually is most serious during the flowering period. The only control is through the selection of Phytophthora resistant varieties.

Pellicularia filamentosa Rogers and Rhizoctonia solani Kuhn are a group of filiform fungal diseases which may attack all varieties of kenaf at any stage of growth and manifest themselves either as damping-off of young plants or in the form of basal stem lesions found on older plants just above the soil level.

Sclerotium rofsii Sacc., known as collar rot, Sclerotium bataicola Taub., known as carbon rot, and Corticium salmonicolor are soil borne fungi which attack the root system and basal stem portions of kenaf in the later stages of growth. Other root and stem diseases include Macrophomina phaseoli, known as charcoal root rot or ashy stem blight, and Macrophoma urenae.

Ascochyta hibisci-cannabini Chochr. is a seed borne fungus known as leaf spot or canker blight, attacking both leaves and stems, and so

are Fusarium sacrochrom (Desm.) Sacc., Fusarium coeruleum (Lib.) Sacc., and Fusarium oxysporum vasinfectum (Atk.) Snyder & Hansen..

Leveillula taurica (Lev.) Arn. and Botrytis sp. are fungi known as powdery mildew which attack and sometimes cause defoliation of kenaf leaves, as does Phoma sabdariffa Sacc., or leaf spot. They are specially prevalent during periods of high humidity.

- Nematodes

Probably the worst pest attacking H. cannabinus (but usually not H. sabdariffa) are the parasitic root-knot nematodes Meloidogyne spp., which are widespread. The characteristic symptoms of attack are stunted growth and yellow foliage and in many cases the plants die outright when half grown. An examination of the root system will disclose nodular galls the number of which depends upon the severity of the infection. Although H. sabdariffa is strongly nematode resistant, commercial plantings of Thai kenaf in Viet-Nam have not been immune from attack after they had been repeated a number of times, but introductions from Indonesia maintained their immunity. The best method of control is planting on new land or in (heavier) soils where nematodes are not present, or through the use of crop rotation.

Because of the potential future importance of H. cannabinus as a source of pulp for paper manufacture in the southern United States, where root-knot nematodes are found in most soils on which kenaf could otherwise be grown, a great deal of work on the development of resistant varieties has been done by the U.S. Department of Agriculture; this has resulted in the isolation of several moderately resistant varieties which, although by no means immune, are substantially superior to normal varieties and may ultimately prove themselves to be sufficiently resistant to allow kenaf production in infested areas.

As elsewhere, the work in the United States has shown that the (tetraploid) H. sabdariffa produced lower yields than the (diploid) H. cannabinus but has the advantage of being highly resistant to the four major root-knot nematode species (M. incognita, M. javanica, M. arenaria, and M. hapla). A hexaploid cross of the two species (H. cannabinus-sabdariffa) has not yet proven useful. It has very poor seed production characteristics, many plants being sterile, is of a poor plant type, and demonstrates little resistance. Efforts continue to back-cross this hexaploid to H. sabdariffa in the hope of

transferring the H. sabdariffa genomes into a H. cannabinus cytoplasm, possibly with some H. cannabinus genetic material; and to select for fertility within the hexaploid. At the same time, selections are made within H. sabdariffa to increase seedling vigor and yield.

2.7. Seed Production

2.7.1. South Asian Kenaf

So far, only limited efforts have been made towards large scale improved seed production in Northeast Thailand, the only area where there exists organized H. sabdariffa production in the riparian countries. However, such efforts are to be increased under an upcoming World Bank financed upland crop development program for the Northeast.

Most farmers now collect the seed for the following year's crop from their own plantings, without any attempt at selection and frequently from stalks too inferior in development to warrant harvesting. The inevitable result is a progressive deterioration of the crop including, at times, the transfer of seed transmitted diseases from the old to the new crop. Furthermore, the lack of uniformity in the quality and germination of the seed leads to uneven plant growth and a reduction in yield.

In the Northeast, one rai (0.16 ha.) of H. sabdariffa planted specifically for seed production yields an average of 50 to 60 kg. of seed (310 to 375 kg./ha.). Since normal seed requirements are 2 kg./rai (12.5 kg./ha.), each rai (or hectare) of seed plantings will supply sufficient seed for 25 to 30 rai (or hectares) of stalk plantings. Referring then to Chapter I, Section 7. "Kenaf Raw Material Requirements and Supplies", the model whole stalk kenaf pulp mill would need some 5,700 to 6,900 rai of annual improved seed plantings for its 172,000 rai maximum stalk planting area requirements (900 to 1,100 ha. for the 27,500 ha. stalk planting area), and the model kenaf bast ribbon pulp mill would need some 18,500 to 22,200 rai of annual improved seed plantings for its 555,500 rai maximum stalk planting area requirements (3,000 to 3,500 ha. for the 89,000 ha. stalk planting area). Such large scale improved seed production might well be organized under pulp mill auspices.

When kenaf is grown for textile fiber production, good quality fiber and seed can not both be obtained from the same plant, since the retted fiber quality deteriorates if the crop is left standing until the seed matures. This does not apply to whole stalk kenaf for paper pulp production where the stalks can be harvested at the "over-mature" seed bearing stage without adverse effect on the pulping quality, but care will have to be exercised when the stalks are field ribboned for long fiber pulp production; if they are allowed to become excessively over-mature, it is difficult to separate the bast ribbon from the core.

For optimum yield, H. sabdariffa seed should be harvested when about one-third of the seed capsules have dried out, even though the plant may still be flowering. If collection is delayed much beyond this point, there will be a considerable loss of seed due to capsule shattering. For harvesting, the tip of the plant which bears the capsules is cut off just below the lowest capsule. The tips are then loosely bundled and shocked for drying, a process which may require up to two weeks before they are ready for threshing.

The simplest way of threshing is to beat the dry stalk tip bundles with a stick and then winnow the seed by hand in order to remove dust and foreign matter. In any large scale seed production operation the seed should obviously be machine threshed and machine cleaned.

Freshly harvested, well cleaned kenaf seed may have a germination rate as high as 96 to 98 percent. However, the seeds have a high oil content and tend to lose viability rapidly under hot and humid conditions. Experiments with jute seed in India have shown that freshly harvested seed contains in excess of 20 percent of moisture. After two days of drying in the sun, the moisture content falls to about 17 percent, after three days to 9 percent, and after four days to some 7 percent. Hence, four days of sun drying is a minimum requirement and the seed should be turned over frequently during that period.

Various fungi and insects may be present in the seed which may seriously affect its viability or transmit certain blights and diseases. Chemical desinfectants are recommended for seed treatment prior to storage. Great care must, however, be taken in the choice of desinfectant since some of them may reduce seed germination very substantially. Also, treated seed tends to lose viability more quickly than untreated seed when exposed to dampness.

Kenaf seeds are stored in a variety of containers such as gunny bags, tin or galvanized iron bins, glass bottles with corks, earthen pots and others. The gunny bags should be lined with plastic to insulate the seed against dampness. In India, the farmers often store their jute seed in earthen pots fitted with lids sealed with clay to keep them airtight and the seed is mixed with wood ash to protect it against insects; the pots are then put in a dark cool place or hung from the roof. In a large scale seed production operation, the seed should be stored in plastic lined gunny bags kept in an air-conditioned warehouse.

2.7.2. Western Hemisphere Kenaf

The process of producing H. cannabinus seed is similar to that described above for the H. sabdariffa species. However, as a result of its faster growing period and because of the desirability of having the capsules mature after the end of the rainy season, H. cannabinus crops from which seed is to be collected will have to be planted somewhat later in the season. With proper timing, this will not prevent a stalk (or ribbon) and seed crop being harvested from the same planting.

Under reasonably favorable soil and climate conditions, one acre of H. cannabinus will yield from 500 to 600 lbs. of seed equivalent to 570 to 680 kg./ha. and 90 to 110 kg./rai. Since normal seed requirements for H. cannabinus planted at 7 in. (17 cm.) inter-row spacing are 22 lbs./acre or 25 kg./ha. or 4 kg./rai, each hectare (or rai) of seed planting will supply sufficient seed for 23 to 27 ha. (or rai) of stalk plantings. Referring then again to Chapter I, Section 7. "Kenaf Raw Material Requirements and Supplies", the model whole stalk kenaf pulp mill would need some 500 to 600 ha. of annual improved H. cannabinus seed plantings for its 13,750 ha. maximum stalk planting area requirements (3,200 to 3,700 rai for the 86,000 rai stalk planting area), and the model kenaf bast ribbon pulp mill would need some 1,650 to 1,950 ha. of annual improved seed planting for its 44,500 ha. maximum stalk planting area requirements (10,300 to 12,100 rai for the 278,000 rai stalk planting area). Again, such large scale improved seed production might be organized on the pulp mill's central demonstration farm or by small holders under central farm/nucleus farm supervision.

2.8. Harvesting

2.8.1. Harvesting Periods

For optimum textile fiber production, kenaf should be harvested when it starts flowering, at which time the stalks contain the maximum quantity of good quality fiber. The fiber percentage, tensile strength and diameter all increase up to the flowering stage. It is generally accepted that, at the time of flowering, the vegetative growth of the plant stops (except for some of the late maturing H. cannabinus varieties) and all nutrients which the plant draws from the soil then go into the production of seed; in fact, some nutrients for seed production are drawn from the plant itself. The fiber coarsens and, after a time, fiber weight is actually reduced. There is no question that harvesting much after flowering and the formation of seed capsules results in a lower retted textile fiber yield and in coarser textile fiber of lower quality.

Kenaf is subject to photoperiodism, including both H. sabdariffa and H. cannabinus. This means that, generally speaking, stalk growth takes place during the months with long daylight hours and that the plants start to flower as soon as the period of daylight falls below a certain minimum, regardless of when they have been planted. Nevertheless, a number of less photo-sensitive varieties have been developed and are referred to in the next two following sub-sections.

The optimum harvesting period for pulp and paper production will not coincide with the optimum period for retted textile fiber production. As will be discussed below, kenaf for paper pulp production allows a much greater degree of flexibility where the most suitable harvesting time span will be determined on the basis of such considerations as the harvest periods of competing crops, the type of pulping raw material desired (whole stalk, chopped stalk, ribbon), field processing and storage methods selected, optimum raw material delivery scheduling to the mill, etc.

2.8.1.1. South Asian Kenaf

The period of flowering for H. sabdariffa in Northeast Thailand, at approximately 16 degrees North Latitude, is in late October; it would be somewhat earlier for the standard Thai varieties in southern

Cambodia and, say, in Darlac Province in South Viet-Nam, at about 12 degrees North Latitude, due to the shorter daylight period closer to the Equator. However, the H. sabdariffa varieties of Indonesian origin should be substantially less photo-sensitive than the Thai varieties, since they have been developed at the Bogor Industrial Crops Research Station which is situated only 7 degrees south of the Equator.

In view of its comparatively slow stalk growth - 140 to 160 days to maturity - and since harvesting should obviously not take place before maximum or close to maximum stalk growth is attained, the South Asian kenaf varieties should not be harvested in the Mekong Basin area before about mid-October and even then that early only if bast ribbon is to be produced, since it would become difficult to strip the bast off the central core once the stalks have become excessively over-mature and have dried out, say after mid-December, by which time the bast stripping operation should be completed. It is anticipated, nevertheless, that many small holders, particularly in Northeast Thailand, will start their harvest in September as they are used to do for retted textile fiber production.

At the other extreme, for whole stalk or chopped whole stalk raw material production, there is no time limitation as far as stalk yield or pulping quality is concerned prior to the start of the next rainy season in April/May, although there would probably be such a limitation in practice as a result of the farmer's desire to realize his profit from the sale of his kenaf crop, to grow another crop on the same land, or to prepare the land for the following rainy season crop.

2.8.1.2. Western Hemisphere Kenaf

The flowering period for the H. cannabinus varieties of standard photo-sensitivity (Cuba 108, Cuba 2032) in Northeast Thailand is during the second half of August; again, it would be somewhat earlier further south in the Mekong Basin area for these same two varieties, as the length of daylight decreases with decreasing North Latitude from the Equator. However, as indicated in Section 2.2.2. of this present Chapter V, H. cannabinus varieties with varying degrees of photo-period response have been developed; by staggering the planting dates, using the optimum variety for each planting date, and as a result of the more rapid stalk growth - 110 to 125 days to maturity - the harvest period for H. cannabinus bast ribbon production in the Basin area could be extended from early August to about mid-January, before the stalks from the latest sowing dry out to such an extent that ribbon

stripping becomes inefficient.

As in the case of H. sabdariffa, for whole stalk or chopped whole stalk production, there is no time limitation for H. cannabinus beyond which stalk yields (for purposes of conversion into pulp) or pulping quality would deteriorate to an unacceptable degree.

2.8.2. Harvesting Methods

In kenaf for paper pulp production, the optimum and/or adopted harvesting method will depend on both the kenaf production system (small holder, nucleus farm assisted small holder, commercial plantation) and the pulping raw material to be produced (whole stalk, chopped whole stalk, ribbon).

The standard method of harvesting kenaf stalks is to cut them with a bushknife and to tie the stalks into bundles of 15 to 20 cm. diameter. The stalk bundles are then shocked, i.e. they are placed in upright stacks in the field, and left standing for three to four days to allow the leaves to dry out so that they can be shaken off before the stalks are transported to the retting facility. Some farmers cut off about 30 cm. (1 ft.) from the tip end of the stalks before shocking, since the tip contains no commercially useful fiber, and the same procedure should be used in kenaf for paper pulp production.

In certain areas of the Northeast, where the soil is very sandy, the stalks are harvested by pulling them out of the ground and then cutting off the roots with the bushknife. It has been stated that the kenaf roots furnish the same quality pulping raw material as the remainder of the stalk so that, for subsequent pulping, it may be advantageous not to remove the roots, although the feeder roots should probably be trimmed off for ease of handling.

2.8.2.1. Whole Stalk Production

For whole stalk pulping raw material production by small holders, the traditional method of kenaf stalk harvesting described above is adequate and suitable. As stated, some 30 cm. or more of the stalk tip should be cut off before the stalks are bundled and shocked, or as much as is necessary to remove the immature tip portion which is characterized by a soft and flexible core, an abundance of leaves and,

in the later stages of development, the presence of seed capsules. Any leaves or seed capsules then still remaining on the top portion of the stalk should be stripped or trimmed off. If the stalks have been harvested after the seed capsules have matured, the cut off stalk tips can be threshed for seed production.

Stalk harvesting in larger operations can be mechanized to the extent that the stalks can be cut by a tractor side-mounted cutter bar; the cut stalks would then have to be collected, de-topped and tied into bundles by hand in the same way as the hand harvested stalks. The next further step towards mechanization would be the use of a high crop harvester such as has already been used experimentally in plantation scale kenaf for textile fiber production in Africa and Latin America; this machine cuts and bundles the stalks and is also equipped with an optional topping device which, however, has not proven very effective so far. It should also be feasible to adapt one or the other of the modern sugar cane field harvesters to kenaf harvesting, but it is strongly doubted that any of these mechanized harvesting methods will be applied to kenaf for paper pulp production in the Mekong Basin anytime soon, since small holder production will obviously continue to predominate in the region.

2.8.2.2. Chopped Stalk Production

Small holder chopped kenaf stalk production for paper pulp would consist merely of adding a manual chopping operation to the whole stalk harvest described above. Alternatively, the stalks could be delivered by the farmers to a central chopping plant, as indicated in Section 4.1. below.

Extensive mechanized kenaf harvesting tests were carried out in 1968 by the Agricultural Engineering Department of Texas A&M University with the aim of evaluating different methods of harvesting the entire plant as a raw material for paper pulp. The equipment used included forage harvesters, flail choppers, mower-crimpers, row binders, and field balers, and the stalks were either chopped, chopped and baled, whole stalk baled, or saw cut. The tests were made on kenaf planted in double rows 25 cm. apart and planted on seedbeds spaced at 1.00 m. centers, with average plant heights of 3.20 to 3.50 m. (11 to 12 ft.) and base diameters ranging from 18 to 25 mm. (3/4 to 1 in.), and stalk populations in the 250,000 plants per hectare (100,000 plants per acre) range. Hence, apart from the inter-row spacing, the kenaf crop characteristics closely approached anticipated H. cannabinus crop

conditions in the Lower Mekong Basin area. The results of the above tests may be summarized as follows:

- The forage harvesters worked satisfactorily on plants not exceeding 3.50 m. in height and 2.5 cm. base diameter, but left a minimum 10 cm. high stubble in the field resulting in appreciable yield losses. The self-propelled forage harvester suffered from serious wrapping problems, poor shearing action near the base of the blades causing the bast to wrap tightly around the main shaft, and to prevent subsequent stoppage or overheating, the material had to be removed from the shaft between each load. No such problems were encountered with the reel-type cutting mechanism used on the pull-type forage harvester.
- When the stalks were harvested with a flail chopper, they had to be pushed over to a height of approximately 30 cm. from the ground in order for the material to be harvested by the cutting mechanism; this resulted in a low harvesting efficiency, since many stalks broke off or were uprooted and were not harvested.
- For field baling, the stalks were cut and conditioned with a mower-crimper and discharged into a windrow after passing through the rollers; attempts at achieving a satisfactory crushing roll feed with stalks taller than 2 m. were unsuccessful. The follow-up wire-tying baler worked satisfactorily on the crushed material from the windrows but not on uncrimped material cut by a sickle-bar mower.
- Whole stalk cutting and bundle tying with a high-crop harvester worked well on kenaf up to 2 m. in height; when harvesting larger plants, two men in addition to the operator were required for continuous operation - one to assist in holding the plants in a vertical position in the tying chamber, and one to assist the knockout mechanism in discharging the bundles from the machine.
- The harvesting capacities, in tons of dry matter per hour, for the machines used in the test are given in Table V.3. and presented graphically in Fig. V.1., where the effective capacity for each machine was reduced by time lost in turns at the end of the rows representing from 10 to 15 percent of the total time.
- The cost of operation for each of the foregoing kenaf harvesting systems is shown in Table V.4. Information used in computing costs included estimated equipment life, repair cost, normal years of use, remaining farm values, and interest at 6 percent.

Kenaf Harvesting Machine Capacities
Texas, U.S.A., 1968

Machine	Average Capacity (Tons/Hr.)*	Field Efficiency (%)	Effective Capacity (Tons/Hr.)*
Forage Harvester, S.P. 3/4 in.	12.90	85	10.96
Forage Harvester, S.P. 3/8 in.		55**	7.09
Forage Harvester, S.P. 3 in.	14.98	85	12.73
Forage Harvester, S.P. 3 in.		55**	8.24
Forage Harvester, Pull Type	9.00	85	7.65
Flail Chopper	4.88	85	4.15
Mower-Crimper	7.26	85	6.17
Baler	7.20	85	6.12
Row Binder	2.90	85	2.47

* Oven dry basis.

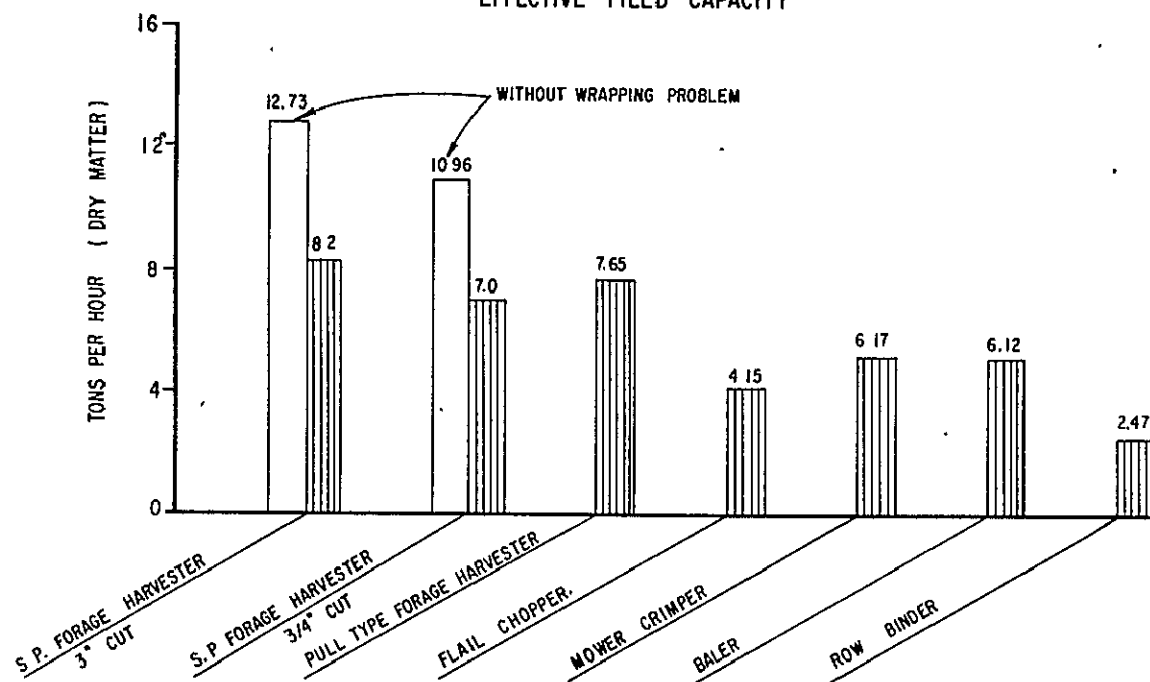
** Forage harvester efficiency with wrapping problem.

Table V.3.

EFFECTIVE FIELD CAPACITY OF KENAF HARVESTING MACHINES

TEXAS, U. S. A., 1968

EFFECTIVE FIELD CAPACITY



Kenaf Harvesting Machine Costs
Texas, U.S.A., 1968

System of Harvest	Effective Capacity (Tons/Hr.)	Machine Cost (Per Hr.)	Machine Cost (Per Ton)*
Forage Harvester, S.P. 3/4 in.	10.96	\$11.50	\$51.06
	7.08**	11.60	1.64
Forage Harvester, S.P. 3 in.	12.73	11.60	0.91
	8.24**	11.60	1.41
Forage Harvester (Pull) 3 in., with 95 HP. Tractor	7.65	6.31	0.82
Flail Chopper with 95 HP. Tractor	4.15	4.80	1.16
Baler, with 35 HP. Tractor and Crimper with 25 HP. Tractor	6.12	6.23	1.51
		3.03	
Row Binder with 25 HP. Tractor and Loader with 25 HP. Tractor	2.47	5.01	2.77
		1.84	

* Oven dry kenaf.

** At 55% efficiency with wrapping problem.

Table V.4.

- The number of men required for each machine and each harvesting system is given in Table V.5. Only two men were required with the forage harvesters and the flail choppers, namely the machine or tractor operator and the truck driver. With the bale system of harvesting, one operator was required for the mower-crimper and one for the baler, and four men were used in loading the bales in the field - one as truck driver, one to stack the bales on the truck, and two to lift the bales onto the truck. Six men were required in the row binder system - two on the binder in addition to the tractor driver, one to operate the front-end loader, one to assist in lifting the bundles onto the loader, and one to drive the truck.
- The total costs per ton for each kenaf harvesting system are shown graphically in Fig. V.2. They include machinery, hauling and labor, the latter calculated at a rate of \$1.50 per hour. The data represent the total cost of harvesting the kenaf from the standing stalk and placing it onto the truck in the field, but they do not include the cost of transportation to a central loading or storage area.

Summarizing the foregoing, the above 1968 tests in Texas showed that kenaf could be harvested in the chopped form, with the then commercially available equipment and at the then prevailing wage rates, for as low as \$1.35 per ton of dry matter, or approximately 15 percent of the cost of harvesting an equivalent unit of wood. The principal limiting factor in this system of harvesting kenaf was storage, if the stalks were harvested at moisture levels above 35 percent (see Section 4.4. below). The bale system of harvesting with commercial equipment was only effective in kenaf with a maximum height of 2 m. and was more costly than the forage harvesting system, but had the advantage of lower bulk density of the end-product. The whole stalk harvesting and bundling system by means of a row binder had the limitations of comparatively high costs due to low equipment capacity and excessive labor requirements, as well as of low bulk density. Reference to Table V.4. and Fig. V.2. will show, however, that more than 70 percent of the total \$7.75 per ton harvesting cost in this system is represented by labor costs, and the system does indeed deserve continued consideration in South Asia with its substantially lower wage rates.

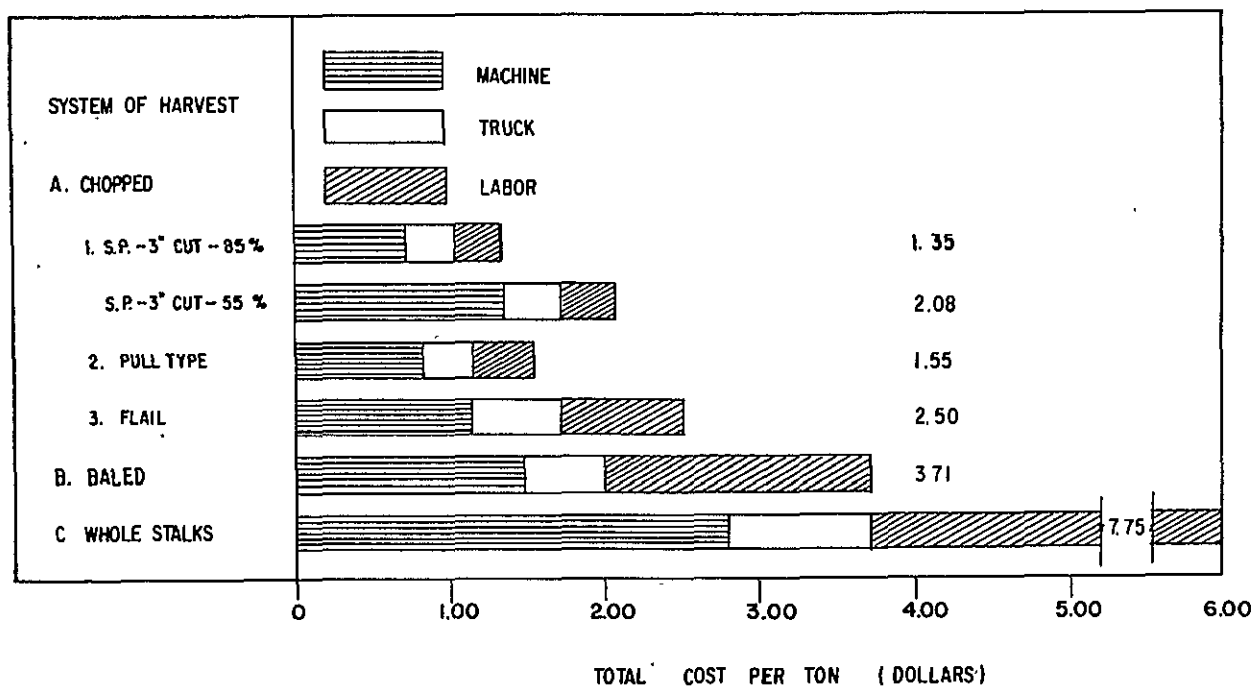
Similar mechanized kenaf harvesting tests to those described above were carried out by the United States Department of Agriculture at Tifton, Georgia, in 1974 and similar conclusions as to the relative merits of the different harvesting systems were reached.

Labor Requirements for Mechanized Kenaf Harvesting
Texas, U.S.A., 1968

System of Harvest	Machines Requiring Operator	Number of Men	Total Men Per System
Forage Harvester S.P.	Harvester	1	2
	Truck	1	
Forage Harvester, Pull Type	Harvester (Tractor)	1	2
	Truck	1	
Flail Chopper	Harvester (Tractor)	1	2
	Truck	1	
Baler	Cutter-Crimper	1	
	Baler	1	6
	Truck	4	
Row Binder	Tractor	1	
	Binder	2	6
	Loader	2	
	Truck	1	

Table V.5.

TOTAL COST OF MECHANIZED KENAF HARVESTING
TEXAS, U. S. A. , 1968



It is emphasized that the cost figures cited in the foregoing were established in 1968 and are now outdated. In 1975, the USDA carried out a follow-up investigation on the economics of kenaf for paper pulp production in the United States and this is discussed in Chapter I, Section 2.2., of this Study. Nevertheless, the information contained in this sub-section is of value as far as machine time and labor requirements and the relative costs of the different chopped stalk harvesting systems are concerned.

2.8.2.3. Ribbon Production

The term "ribboning" is applied to the process of manual or mechanical stripping of the long fiber bearing bast of the kenaf stalk from the central woody core. The resulting strip of bast is called a "ribbon".

The South Asian kenaf grown in Northeast Thailand is not now ribbioned but instead the entire stalks are retted and the textile fiber then stripped off by hand and washed, although the kenaf growers in the water poor Northeast could greatly profit from preliminary bast stripping which reduces transportation costs to the retting facility by some 90 percent and water requirements by about 80 percent. However, manual jute ribboning has been practiced extensively in Viet-Nam in the past.

The first step in hand ribboning of kenaf is to loosen the bast from the butt-end (lower end) of the harvested stalk and to break off some 10 to 20 cm. (4 to 8 in.) of the woody core. The free end of the bast is then grasped firmly and pulled around an upright pole thus separating it from the stalk. The worker may either sit or stand during this operation, and sometimes a second upright pole is used to guide the stalk core. Another method is to pull the bast over the edge of a horizontal table; a refinement of this method is to install bracket mounted bicycle wheel hubs at each end of the table and to pull the ribbon over these rollers thus greatly reducing friction and lightening the work load.

Various types of kenaf ribboning machines have been developed over the years, from simple raspadors to sophisticated automatic harvester/decorticators. The raspador type units - some of which were used in Viet-Nam during the 1960's - were originally developed for the decortication of such hard (leaf) fibers as sisal and henequen and

produce excessive waste losses on the much weaker bast fibers like kenaf and jute. None of the automatic harvester/decorticators (also based on the raspador principle) have proven themselves in commercial field operation, primarily because they were too complicated and not sufficiently rugged; they were also too heavy for operation in muddy fields during the rainy season. The ribboning machines in regular use in kenaf operations in Africa and Latin America are medium output (1 to 2 acres, 0.4 to 0.8 ha., 2.5 to 5 rai per day) units, rubber tyre mounted and equipped with their own diesel power plant; both stalk feeding and ribbon removal are done by hand. Since they "strip" rather than decorticate the stalks, as the raspador type machines do, the ribboning action closely duplicates hand stripping and fiber losses are minimal or zero.

Manual and mechanized kenaf stalk ribboning for textile fiber production and subsequent ribbon handling have been standard practice for more than 25 years in commercial operations and will require only minimal adaptation to make them directly applicable to kenaf ribboning for paper pulp production.

3. Whole Stalk Kenaf Raw Material

3.1. Whole Stalk Kenaf Raw Material Requirements

This subject has already been discussed in Chapter I, Section 7.1.1., of this Study. As indicated in that section, the selected output of the whole stalk kenaf pulp mill, for purposes of this Study, is 70,000 air dry metric tons (ADMT) per year of bleached pulp, and it is assumed that the bleached pulp recovery rate from whole stalk raw material amounts to 35 percent. The 70,000 ADMT/year whole stalk kenaf pulp mill will then require 205,714 field dry metric tons (FDMT) or, rounded off 206,000 FDMT/year of whole stalks or, on the assumption of a 12.5 percent moisture content in the FD stalks, 180,000 oven dry metric tons (ODMT) annually.

In Section 6 of Chapter I, six potential future kenaf pulp mill sites in the Mekong Basin area have been selected on the basis of such primary criteria as the availability of water and of communication facilities. Since four of these potential sites are located in Cambodia and Viet-Nam and are, thus, presently inaccessible to the Consultants, the two potential sites in Northeast Thailand, Sites I and II, are discussed in detail in this Study and that on the assumption that the conclusions reached as to raw material supplies and pulping processes will, with suitable but comparatively minor modifications, also be applicable to the remaining four mill sites.

Although the model mills at Sites I and II respectively are both designed to process the full range of kenaf raw materials, from whole stalk to bast ribbon and any mixture of these two, and in order to avoid duplication, whole stalk kenaf raw material production and procurement only will be described in detail with respect to Mill Site I and bast ribbon production and procurement with respect to Mill Site II. It will also be assumed that, because of its central location in the traditional *H. sabdariffa* production area in Northeast Thailand, the mill at Site I will exclusively use South Asian kenaf as its raw material.

Finally, for the reasons cited in Chapter I, Section 6., it is assumed that the whole stalk kenaf pulp mill will be located near the village of Nam Phong in Amphur Nam Phong, Changwat Khon Kaen, in the Ubolratana Resettlement Area at a site west of the Friendship Highway, some 33 km. north of the town of Khon Kaen.

3.2. Kenaf Stalk Yield per Unit Area

Before the overall raw material supply situation - existing or potential - can be assessed, the anticipated yield of whole kenaf stalks per unit area must be evaluated. Such yield will depend on the species and variety planted, soil and climatic conditions, plantation management, and similar factors.

In the following, past stalk yield investigations for both H. sabdariffa and H. cannabinus will be reviewed and yield projections for both species under Lower Mekong Basin conditions will be discussed.

3.2.1. South Asian Kenaf

For the H. sabdariffa species, anticipated whole stalk yields under Northeast Thailand conditions will be evaluated herein. Similar yields should be obtainable in other Southeast Asian kenaf production areas in Cambodia, Laos and Viet-Nam. It must be emphasized that, so far, no extensive field tests have been carried out on this subject for H. sabdariffa. Detailed data are indeed available on retted (textile) fiber yields for Thai kenaf but, since the central core material is always discarded in retted fiber production, no interest existed in the past in establishing whole kenaf stalk yield data. Nevertheless, some preliminary investigations have been undertaken in Thailand.

The Applied Scientific Research Corporation of Thailand (ASRCT) has carried out at least one field test on whole stalk yields and that at Ban Por Dange, Changwat Khon Kaen, in January 1974. Although the test was very limited in scope and still leaves many unanswered questions, its results can be used to at least narrow down the range of stalk yields that can reasonably be anticipated.

Five random plots of 16 sq.m. each were selected in farmers' land and the stalks harvested and shocked for field drying for a 10-day period, after which they were transported to the ASRCT premises in Bangkok and oven dried for 12 hours at 100°C. The stalks were weighed at harvest (green weight), after field drying, and after oven drying; the results, converted into kilograms per rai and per hectare, are listed in Table V.6. for the two broadcast planted and the three row planted plots respectively and are discussed as follows:

H. Sabdariffa Stalk Yields, Thailand

Plot	% Kenaf Variety		Green Weight		Field-Dry Weight		Oven-Dry Weight	
	Red	Green	Kg./Rai	Kg./Ha.	Kg./Rai	Kg./Ha.	Kg./Rai	Kg./Ha.
<u>Broadcast Planted</u>								
1	10	90	5,200	32,500	2,723	17,019	2,072	12,952
2	60	40	3,400	21,250	1,498	9,363	1,175	7,344
Aver.	35	65	4,300	26,875	2,110	13,188	1,624	10,150
<u>Row Planted</u>								
3	0	100	5,900	36,875	3,623	22,644	2,704	16,900
4	10	90	4,300	26,875	2,795	17,469	1,945	12,156
5	20	80	2,800	17,500	1,892	11,825	1,532	9,575
Aver.	10	90	4,333	27,100	2,770	17,300	2,060	12,875

Table V.6.

Broadcast vs. Row Planting:

It would be unreasonable, at this time, to use the stalk yield figures from row plantings - which always produce higher yields than the traditional broadcast planting method - since row planting has, so far, only been adopted by a small minority of kenaf farmers in Northeast Thailand. However, the table shows that row planting increases stalk yields by some 25 percent over broadcast planting.

Red vs. Green Kenaf:

Actual distribution of red and green variety kenaf plantings in the Northeast are indeed in the approximate 35 to 65 ratio as shown for the broadcast planted plots in Table V.6.

The average oven dry (OD) weight figure of 1,625 kg./rai (10,150 kg./ha.) in Table V.6., therefore, is assumed to most closely approximate obtainable kenaf stalk yields in the Northeast. Nevertheless, for purposes of this Study and pending the results of much more detailed investigations during the 1975/1976 and subsequent seasons, this figure is reduced by a 25 percent safety factor to 1,218 kg./rai (7,600 kg./ha.) of OD stalks and, rounded off downwards, to 1,200 kg./rai (7,500 kg./ha.) of OD stalks; furthermore, this yield of 1,200 kg./rai is assumed to represent FD (field dry = 12½% moisture content) stalks, rather than OD stalks.

However, since it is felt that, with only slight improvements in seed selection, extension services and cultural practices, substantially higher whole stalk yields can readily be obtained, a yield range of 1,200 kg. to 1,500 kg./rai (7,500 to 9,375 kg./ha.) has been used, when appropriate in this Study, in calculating raw material planting area requirements in relation to pulp mill outputs and for similar purposes.

3.2.2. Western Hemisphere Kenaf

An intensive research and field test program on H. cannabinus yields has been carried out by the USDA over a number of years as part of its investigations into the use of kenaf for paper pulp and this

program is still in progress. Similar but much more limited work on the potentials of Western Hemisphere kenaf as a pulping raw material has been undertaken in Australia, Sri Lanka and some African and Latin American countries.

In the United States, kenaf for paper pulp development work was initiated in the late 1950's with a view to systematically examining the potential value of this new pulping raw material as a future standby source for the industry in consideration of the steadily rising demand for paper products and the equally steadily declining availability of woody raw materials over the long term. At that time, very substantial farm areas were kept out of production in the United States in order to avoid excessive food and fiber over-production and it was felt that such areas could potentially be planted to a crop such as kenaf and thus provide a source of revenue to the farmers without adding to the then existing food and (textile) fiber glut. The world food and fiber supply situation having changed drastically in recent years, abundant potential kenaf growing areas not required or more advantageously employed for the production of other crops are no longer available in the United States, although substantial such areas still exist, particularly in the Southeast and Southwest, where kenaf could compete successfully with other commercial crops.

As a result of the above reasoning underlying the United States kenaf development program, the research and field test programs included areas as far north as Illinois and as far south as Georgia, Texas and Florida. In view of the substantial climatological differences, kenaf yields and stalk growth obviously greatly varied between the northern and southern test areas. Since kenaf is essentially a tropical crop, yields in the South exceed those further north, but even then climatic conditions in the test areas in the southern United States are not as favorable to kenaf production as in the tropics including, for example, such limitations on planting and harvesting periods as frost in winter or lack of rainfall during the summer growing season. Furthermore, the soils in the potential somewhat marginal kenaf production areas in the southern United States, where kenaf would not compete with other more essential crops, are generally fairly light and thus harbor nematodes, a destructive rootknot disease to which H. cannabinus is highly susceptible and which thus reduces stalk yields. Also, since the kenaf harvest in the United States would have to be completely mechanized for it to be commercially viable and since, so far, only standard forage harvester-choppers are available for that purpose, the kenaf has to be planted at a much greater distance between the rows than is customary in the

tropics. All of the above factors and considerations combined must reasonably be expected to result in lower yields than should be obtainable in the tropics with H. cannabinus. Hence, the following discussion of Western Hemisphere kenaf yields based upon the work of the USDA can only provide a general guide to the yields that might be anticipated in the tropics (and parts of the sub-tropics) in general and the Mekong Basin countries in particular, where it is emphasized most strongly that only research and field trials in the actual potential kenaf production areas themselves will provide reliable yield information.

Under the USDA H. cannabinus test program, actual OD whole stalk field yields have ranged from as little as 1.5 tons/acre (3.75 tons/ha.) for a rootknot nematode susceptible variety planted in a heavily nematode infested area to more than 20 tons/acre (50 tons/ha.) on good nematode-free soil and with irrigation. The USDA technicians have concluded that, pending the development of nematode-resistant H. cannabinus varieties, whole stalk OD yields of 6 to 8 tons/acre (15 to 20 tons/ha. - 2.4 to 3.2 tons/rai) are a reasonable expectation on the better quality soils in the southern United States, where the emphasis is placed on low nematode infestation as far as soil quality is concerned. Since such heavier and hence less nematode infested soils would be selected for Western Hemisphere kenaf production in the riparian countries - whereas the lighter, sandier and hence more nematode infested soils would be reserved for South Asian kenaf - at least similar whole stalk yield ranges can reasonably be anticipated in the Lower Mekong Basin.

The USDA tests have led to the conclusion that plant densities, at harvest, of 200,000 to 300,000 plants per hectare (80,000 to 120,000 plants per acre) result in optimum whole stalk yields under southern United States conditions. This corresponds to the experience gained with kenaf for textile fiber production in the tropics, where ultimate plant densities at harvest should be in the 250,000 plants per hectare (100,000 plants per acre) range for optimum retted fiber yields.

The USDA also concluded that stem yields from harvests made several weeks before frost would be markedly lower than those from harvests immediately before or after a killing frost and that stem yields would be gradually reduced because of loss of harvestable plants due to lodging as well as because of leaching of the standing crop by rain, as the harvest is delayed after frost. The foregoing USDA conclusions indicate that, although frost conditions of course

never exist in the potential kenaf production areas in the riparian countries, research work into kenaf for paper pulp production in the region must definitely include time-of-harvest investigations since it appears that a harvest substantially delayed beyond the flowering period - the optimum harvest time for maximum quantity and optimum quality retted kenaf fiber production - may well increase whole stalk yields. Similar tests must be carried out with regard to bast ribbon yields. Finally, the influence of the time-of-harvest on the pulp yields from whole stalk kenaf and the core and bast fractions must be examined.

As anticipated, stalk yields were found to be highest for the earliest plantings which allowed maximum stalk development prior to flowering as a result of the shortening in daylength at which time the vegetative growth of the stalk in most kenaf varieties is arrested. In fact, under southern United States conditions, yields from May 1 plantings were some 25 percent higher than yields from June 1 plantings.

In 1968, a variety-fertility test with four replications was planted at Gainesville, Florida, on March 22 on bedded rows spaced 38 in. (95 cm. !!!) apart at a seeding rate of 6 lbs./acre (6.8 kg./ha.). The plots were fertilized at planting with 100 lbs./acre (114 kg./ha.) of nitrogen, 44 lbs./acre (50 kg./ha.) of phosphorus, and 83 lbs./acre (94 kg./ha.) of potassium. A side dressing of two nitrogen and three potassium levels was applied on May 15. In the analysis of the data, there were no significant effects from the fertilizer treatments on the fertilizer-variety interaction. OD stalk yields of the six varieties tested were as follows:

<u>Variety</u>	<u>Mean Dry Matter Yield</u>	
	<u>Tons/Acre</u>	<u>Tons/Ha.</u>
Everglades 71	9.16	22.9
Everglades 41	8.13	20.3
G-4	7.53	18.8
G-45	7.09	17.7
C-2032	6.23	15.6
C-108	5.83	14.6

Tentatively interpreting the above test results as far as their applicability to Lower Mekong Basin conditions is concerned, it is concluded that:

- Although the Everglades 41 and 71 varieties have been developed for United States and, specifically, southern United States conditions and their photo-sensitivity might not be suitable for more tropical areas (Central Florida is some 30 degrees north of the Equator), they should be tested under the subject Kenaf for Paper Pulp Development Program (a) because of their high yield potential, and (b) because of their (limited) nematode resistance;
- Since the above listed yields were obtained at the very wide row spacing of 95 cm. compared to the 17.5 cm. (7 in.) row spacing commonly used for H. cannabinus plantings in the tropics and under soil and climatic conditions certainly not more favorable than those under which the crop would be planted in the riparian countries, similar if not higher yields should be obtainable in the Lower Mekong Basin;
- The widely accepted G-4/G-45/C-2032 H. cannabinus variety combination should be used for the Kenaf for Paper Pulp Program developmental work (although the Everglades 71 and 41 varieties should be further tested).

Hence, for purposes of this Study and although substantially higher stalk yields will likely be obtainable in practice, an average H. cannabinus yield range of 6 to 8 tons/acre (15 to 20 tons/ha. - 2.4 to 3.2 tons/rai) of OD whole stalks will be assumed; furthermore, as in the case of South Asian kenaf, this OD stalk yield will be assumed to represent the FD (field dry = 12.5 percent moisture content) stalk yield, as an additional safety margin.

3.3. Kenaf Production Areas and Whole Stalk Supplies Within Economic Distance of Mill Site I

As indicated in Section 3.1. above, whole stalk kenaf raw material supplies are discussed in detail for the selected Mill Site I north of Khon Kaen and bast ribbon supplies will be given priority as far as Mill Site II east of Ubon Ratchathani is concerned. It is again pointed out that this is done only to avoid duplication of raw material supply discussions since, as emphasized in the above cited section, the model mills developed in this Study are designed to process either of these two types of raw material and/or any blend thereof.

For purposes of whole kenaf stalk supplies, it is assumed herein that the stalks can be trucked economically to the mill site from a distance of up to 160 kilometers. Hence, a listing has been prepared of all kenaf producing Amphurs (Districts) within that road distance from Mill Site I at Nam Phong (Table V.7.). The table shows the annual kenaf planting areas, by Amphur, for the 1970 to 1974 period, the average and maximum planting areas during that same period, and the average and maximum planting areas, by Amphur and overall, grouped by transportation distance from Mill Site I. Fig. V.3. shows this latter information graphically and Plate V.1. locates the selected Amphurs on a map of the central and northern areas of Northeast Thailand.

On the basis of a total annual FD kenaf stalk requirement of 206,000 tons and an average FD H. sabdariffa stalk yield of 1,200 kg./rai (7,500 kg./ha.) (Section 3.2.1. above), the stalks from a total annual kenaf planting area of 172,000 rai (27,500 ha.) will be required to satisfy the raw material requirements of the pulp mill. At the same time, it is assumed that the pulp mill will not attempt to purchase more than 25 percent, on the average, of the available kenaf so as to avoid possible recriminations from the jute mills or the kenaf (fiber) balers and exporters that the pulp mill endangers their traditional sources of raw material supply (see Chapter I, Section 7.2.2.), although it can reasonably be anticipated that the pulp mill could receive the stalks from a much higher percentage of the planting area within a, say, 60 km. road distance particularly since, with the exception of the Khon Kaen Jute Mills at Tha Phra and the Jute & Kapok Industries, Ltd., near Udorn, all other jute mills are located south of Nakorn Ratchasima, 200 km. away, and as far south as Bangkok, at a distance of 535 km.; most of the baling plants are, however, located in the Northeast itself.

Kenaf Planting Areas, by Amphur, within Economic Distance
from Mill Site I

Amphur	Distance (km) ⁽¹⁾	Annual Kenaf Planting Area (Rai)					Kenaf Planting Areas (Rai) within Varying Transportation Distance Limits											
		1970	1971	1972	1973	1974	1970 to 1974		0 to 20 km		20 to 40 km		40 to 80 km		80 to 120 km		120 to 160 km	
							Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum		
<u>Changwat Khon Kaen</u>																		
Muang Khon Kaen	33	58,915	77,312	74,236	76,808	88,318	75,118	88,300			77,100	88,300						
Ban Phai	76	54,524	80,765	61,458	67,243	72,570	67,312	80,800					67,300	80,800				
Chonabot	88	18,000	17,000	21,700	23,029	15,280	19,002	23,000							19,000	23,000		
Chumphae	113	18,360	20,560	20,666	18,450	12,450	18,097	20,700							18,100	20,700		
Kranuan	32	23,750	24,200	20,000	20,000	20,000	21,590	24,200			21,600	24,200						
Manchakhiri	100	29,850	30,856	33,219	26,100	20,000	28,005	33,200							28,000	33,200		
Nam-Phong	70	32,640	32,540	15,258	6,950	5,300	18,538	32,600	18,500	32,600								
Nong Rua	79	20,210	25,000	25,800	15,315	10,720	19,409	25,800					19,400	25,800				
Nong Song Hong	132	1,100	3,253	4,450	2,746	1,070	2,524	4,500									2,500	4,500
Phon	106	38,121	30,606	33,440	33,664	31,794	33,525	38,100							33,500	38,100		
Phu Wiang	97	32,250	61,990	15,415	15,115	16,435	28,241	62,000							28,200	62,000		
Si Choenghu	147	2,990	5,797	11,624	7,500	20,660	9,714	20,700									9,700	20,700
K. Ubolrat	15	-	-	-	-	7,844	7,844	7,800	7,800	7,800								
K. Weengnoi	52	-	24,576	30,197	34,722	28,736	29,558	34,700					29,600	34,700				
Sub-Total		357,710	434,455	367,463	347,642	351,177	378,477	463,800										
<u>Changwat Udorn Thani</u>																		
Muang Udorn Thani	85	12,000	3,500	11,000	10,000	12,000	9,700	12,000							9,700	12,000		
Ban Dung	155	5,500	5,630	3,730	12,000	12,099	7,792	12,100									7,800	12,100
Ban Phu	138	300	2,240	8,850	23,950	18,000	10,668	24,000									10,700	24,000
Kut Chap	120	-	-	-	8,000	1,000	4,500	8,000									4,500	8,000
Kumphawapi	55	3,500	8,160	4,500	5,000	5,000	5,232	8,200					5,200	8,200				
Na Kiang	160	8,900	4,033	40,000	70,000	25,000	28,587	70,000									29,600	70,000
Nong Bualamphu	131	4,673	6,270	6,270	8,550	6,650	6,483	8,600									6,500	8,600
Nong Han	95	13,000	10,575	14,000	15,000	10,270	12,569	15,000							12,600	15,000		
Nong Muasor	113	-	50,510	22,300	27,780	10,130	27,600	50,500							27,700	50,500		
Nong Sang	158	11,000	1,491	2,895	2,155	3,241	4,156	11,000									4,200	11,000
Phen	124	250	802	820	5,156	2,021	1,810	5,200									1,800	5,200
Sri Buruang	137	1,500	14,230	4,250	7,590	5,500	6,614	14,200									6,600	14,200
Sub-Total		60,623	107,441	118,615	195,181	110,911	126,791	238,800										
<u>Changwat Nong Khai</u>																		
Muang Nong Khai	141	436	490	572	1,480	1,268	849	1,500									900	1,500
Tha Bo	158	293	239	340	1,160	180	442	1,200									400	1,200
Sub-Total		729	729	912	2,640	1,448	1,291	2,700										
<u>Changwat Kalasin</u>																		
Muang Kalasin	121	12,140	16,000	23,000	24,660	19,163	18,993	24,700									19,000	24,700
Kamalasat	146	10,161	15,000	12,000	10,000	12,000	11,832	15,000									11,800	15,000
Nong Kungsri	57	5,900	36,000	57,000	50,000	5,720	30,924	57,000					30,900	57,000				
Sahar Sakhan	148	3,920	4,980	7,180	9,510	7,816	6,681	9,500									6,700	9,500
Somdet	160	1,691	2,375	2,960	4,185	4,765	3,195	4,800									3,200	4,800
Tha Khantho	72	9,025	18,280	21,500	17,800	6,491	14,619	21,500			14,600	21,500						
Yang Thalat	105	31,896	22,152	24,611	27,768	23,974	26,080	31,900							26,100	31,900		
Sub-Total		74,713	116,785	148,251	143,923	79,931	112,324	164,400										

Note: (1) Distance from Mill Site I

Source: Division of Agricultural Economics

Table V. 7. (A)

Kenaf Planting Areas, by Amphur, within Economic Distances
from Mill Site I

Amphur	Distance (km)	Annual Kenaf Planting Area (Rai)							Kenaf Planting Areas (Rai) within Varying Transportation Distance Limits									
		1970	1971	1972	1973	1974	1970 to 1974		0 to 20 km		20 to 40 km		40 to 80 km		80 to 120 km		120 to 160 km	
							Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
<u>Changwat Mahasarakham</u>																		
Muang Mahasarakham	92	46,098	53,482	33,330	51,809	25,315	42,007	53,500								42,000	53,500	
Borabu	120	32,450	57,330	63,063	74,800	51,150	55,759	74,800								55,800	74,800	
Chiang Yun	64	34,753	39,450	37,097	36,830	20,978	33,822	39,500					33,800	39,500				
Kantherawichai	95	24,932	25,021	22,690	18,129	11,540	20,462	25,000								20,500	25,000	
Khosun Pisai	73	44,370	43,225	46,245	49,850	46,350	46,008	49,900					46,000	49,900				
Na Chuak	155	18,800	23,934	38,776	36,478	39,790	31,556	39,800									31,600	39,800
Wapi Pathum	160	51,460	56,600	49,837	64,800	50,300	54,599	64,800									54,600	64,800
Sub-Total		252,861	299,042	291,038	332,696	245,423	284,213	347,300										
<u>Changwat Roi-Et</u>																		
Muang Roi-Et	132	n.a.	20,968	23,941	24,930	20,000	22,460	24,900									22,500	24,900
At Samat	160	n.a.	30,923	28,875	28,875	28,875	29,387	30,900									29,400	30,900
Chaturaphak Phiman	157	n.a.	21,025	8,887	15,559	6,159	12,908	21,000									12,900	21,000
Selaphum	160	n.a.	12,615	13,413	13,739	16,342	14,527	18,300									14,500	18,300
Thawatburi	142	n.a.	2,788	2,805	4,324	3,824	3,435	4,300									3,400	4,300
Sub-Total		n.a.	88,319	77,921	87,427	77,200	82,717	99,400										
<u>Changwat Nakorn Ratchasima</u>																		
Bua Yai	150	38,500	54,965	57,680	69,325	70,387	58,171	70,400									58,200	70,400
Prachai	160	14,999	15,230	15,049	14,510	13,860	14,730	15,200									14,700	15,200
Sub-Total		53,499	70,195	72,729	83,835	84,247	72,901	85,600										
<u>Changwat Chaiyaphoom</u>																		
Muang Chaiyaphoom	180	65,000	64,200	60,000	60,000	58,000	61,440	65,000									61,400	65,000
Ban Thae	98	7,000	7,000	8,000	10,000	6,000	7,600	10,000								7,600	10,000	
Kaengkhro	140	8,850	10,030	10,050	9,650	9,070	9,530	10,100									9,500	10,100
Kaset Sombun	154	7,000	11,300	8,650	12,500	7,000	9,290	12,500									9,300	12,500
Khonsan	143	7,256	5,750	5,700	15,550	10,000	8,851	15,600									8,900	15,600
Khonsawan	155	60,000	60,000	57,000	50,000	46,700	54,740	60,000									54,700	60,000
Phu Kiao	132	16,380	18,300	29,200	24,400	23,800	22,416	29,200									22,400	29,200
Sub-Total		171,486	176,580	178,600	182,100	160,570	173,867	202,400										
<u>Changwat Sakorn Nakhon</u>																		
Sawang Daen Din	137	3,650	2,450	3,262	7,005	2,275	3,728	7,000									3,700	7,000
Sub-Total		3,650	2,450	3,262	7,005	2,275	3,728	7,000										
TOTAL: Rai							1,236,309	1,644,000										
Hectare							(197,809)	(263,040)										
							23,300	40,400										
							(3,728)	(6,464)										
							28,700	112,500										
							(18,000)	(39,488)										
							246,800	317,400										
							(50,784)	(52,608)										
							449,700	537,600										
							(86,016)	(115,840)										

Note: Overall Average Transportation Distance, Kenaf Raw Material, by Weight/Volume = 105 km.

Table V. 7. (B)

KENAF PLANTING AREAS, BY AMPHUR, WITHIN ECONOMIC DISTANCE FROM MILL SITE I

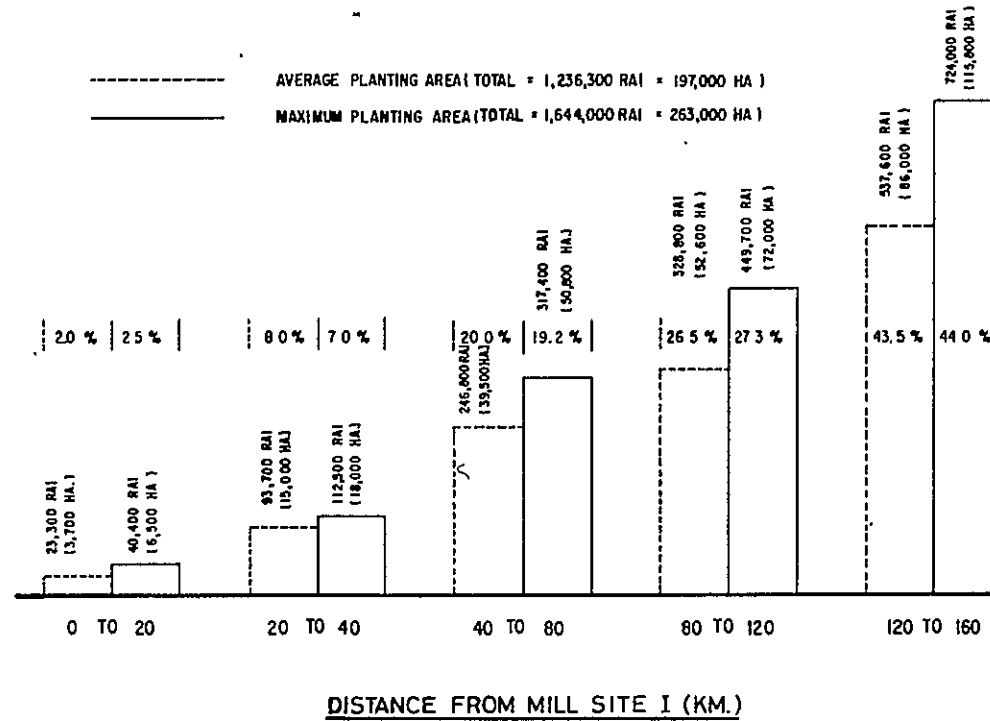
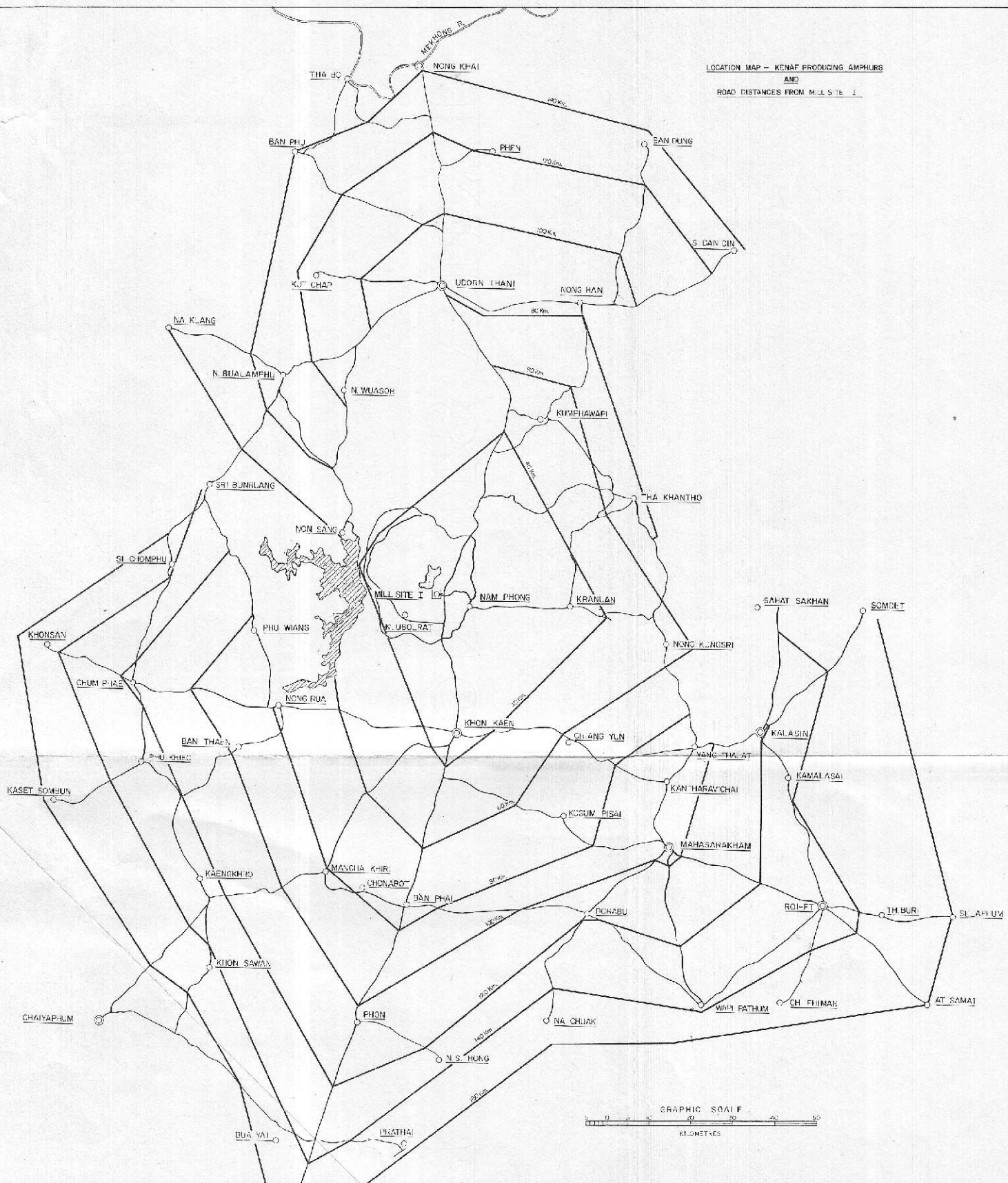


FIG. V.3.

LOCATION MAP - KENAF PRODUCING AMPHURS
AND
ROAD DISTANCES FROM MILL SITE 1



Referring then to Table V.7. and Plate V.1., Amphurs Muang and Tha Bo in Changwat Nong Kai should be eliminated as they are situated close to the economic transportation limit and their production is too small to make their inclusion in the pulp mill supply zone worthwhile; the same applies to Amphur Sawang Daen Din in Changwat Sakorn Nakorn, Amphur Nong Song Hong in Changwat Khon Kaen, Amphur Somdet in Changwat Kalasin, and Amphur Thavatburi in Changwat Roi-Et. Next, Table V.7. is used as a basis for the compilation of Table V.8. which classifies the remaining Amphurs by distance from Mill Site I together with their 5-year average and maximum kenaf production areas, and shows the cumulative planting area totals with increasing distances from that mill site. The cumulative average kenaf production areas, in steps of 250,000 rai (40,000 ha.) and with increasing distances from Mill Site I, are also shown graphically in Plate V.2. The maximum stalk transportation distances can then be calculated from Table V.8. as follows:

Total Field Dry Kenaf Stalk Requirements	206,000 tons
Average Field Dry Stalk Yield	1.2 tons/rai (7.5 tons/ha.)
Hence, Total Raw Material Planting Area	
Required = 206,000 tons/1.2 = Approx.	172,000 rai (27,500 ha.)

Below, a number of assumptions are made as to the percentage of total production the pulp mill at Site I will be able or desire to purchase, and the maximum transportation distance necessary to cover the required planting area is calculated therefrom (a) on the basis of the average annual 1970 to 1974 kenaf planting area for each Amphur, and (b) on the basis of the maximum area planted in any one year during that period. Finally, it is assumed that 75,000 rai (12,000 ha.) will be planted to kenaf specially for the pulp mill in the Ubolratana Resettlement Area - within the boundaries of which Mill Site I is located - and that the balance of the stalk requirements will have to be purchased "outside". The maximum stalk transportation distances are then as follows:

Kenaf Producing Amphurs and Production Areas
in Order of Distance from Mill Site I

Amphur	Distance (km)	Kenaf Planting Area (Rai)				Amphur	Distance (km)	Kenaf Planting Area (Rai)			
		1970 to 1974		Cumulative Total				1970 to 1974		Cumulative Total	
		Average	Maximum	Average	Maximum			Average	Maximum	Average	Maximum
Nam Phong	0	18,500	32,600	18,500	32,600	Muang Kalasin	121	19,000	24,700	716,600	945,000
Kranuan	32	21,600	24,200	40,100	56,800	Phen	124	1,800	5,200	718,400	950,200
Muang Khon Kaen	33	77,100	88,300	117,200	145,100	Nong Bualamphu	131	6,500	8,600	724,900	958,800
K. Weangnoi	53	29,600	34,700	146,800	179,800	Muang Roi-Et	132	22,500	24,900	747,400	983,700
Kumphawapi	55	5,200	8,300	152,000	188,100	Phu Kiao	132	22,400	29,200	769,800	1,012,900
Nong Kungri	57	30,900	57,000	182,900	245,100	Sri Bunruang	137	6,600	14,200	776,400	1,027,100
Chiang Yun	64	33,800	39,500	216,700	284,600	Ban Phu	138	10,700	24,000	787,100	1,051,100
Tha Kantho	72	14,600	21,500	231,300	306,100	Kamalasai	140	11,800	15,000	798,900	1,066,100
Kosum Pisai	73	46,000	49,900	277,300	356,000	Kaengkho	140	9,500	10,100	808,400	1,076,200
Ban Phai	76	67,300	80,800	344,600	436,800	Khonsan	143	8,900	15,600	817,300	1,091,800
Nong Rua	79	19,400	25,800	364,000	462,600	Si Chomphu	147	9,700	20,700	827,000	1,112,500
Muang Udon Thani	85	9,700	12,000	373,700	474,600	Sahat Sakhan	148	6,700	9,500	833,700	1,122,000
Chonabot	88	19,000	23,000	392,700	497,600 ⁽³⁻⁴⁾	Bua Yai	150	58,200	70,400	891,900 ⁽¹⁾	1,192,400
Muang Mahasarakam	92	42,000	53,500	435,000	551,100	Kaset Sombun	154	9,300	12,500	901,200	1,204,900
Nong Han	95	12,600	15,000	447,600	566,100	Ban Dung	155	7,800	12,100	909,000	1,217,000
Kantharawichai	95	20,500	25,000	468,100	591,100	Na Chuak	155	31,600	39,800	940,600	1,256,800
Phu Wiang	97	28,200	62,000	496,300 ⁽⁴⁾	653,100	khonsawan	155	54,700	60,000	995,300	1,316,800
Ban Thae	98	7,600	10,000	503,900	663,100	Chaturaphak Phiman	157	12,900	21,000	1,008,200	1,337,800
Manchakiri	100	28,000	33,200	531,900	696,300 ⁽²⁾	Non Sang	158	4,200	11,000	1,012,400	1,348,800
Yang Thalat	105	26,100	31,900	558,000	728,200	Na Klang	160	29,600	70,000	1,042,000	1,418,800
Phon	106	33,500	38,100	591,500 ⁽³⁾	766,300	Wapi Pathum	160	54,600	64,800	1,096,600	1,483,600
Chumphae	113	18,100	20,700	609,600	787,000	At Samat	160	29,400	30,900	1,126,000	1,514,500
Nong Wuasor	113	27,700	50,500	637,300	837,500	Selaphoom	160	14,500	18,300	1,140,500	1,532,800
Kut Chap	120	4,500	8,000	641,800	845,500	Prathai	160	14,700	15,200	1,155,200	1,548,000
Borabu	120	55,800	74,800	697,600 ⁽²⁾	920,300 ⁽¹⁾	Muang Chaiyaphom	180	61,400	65,000	1,216,600	1,613,000

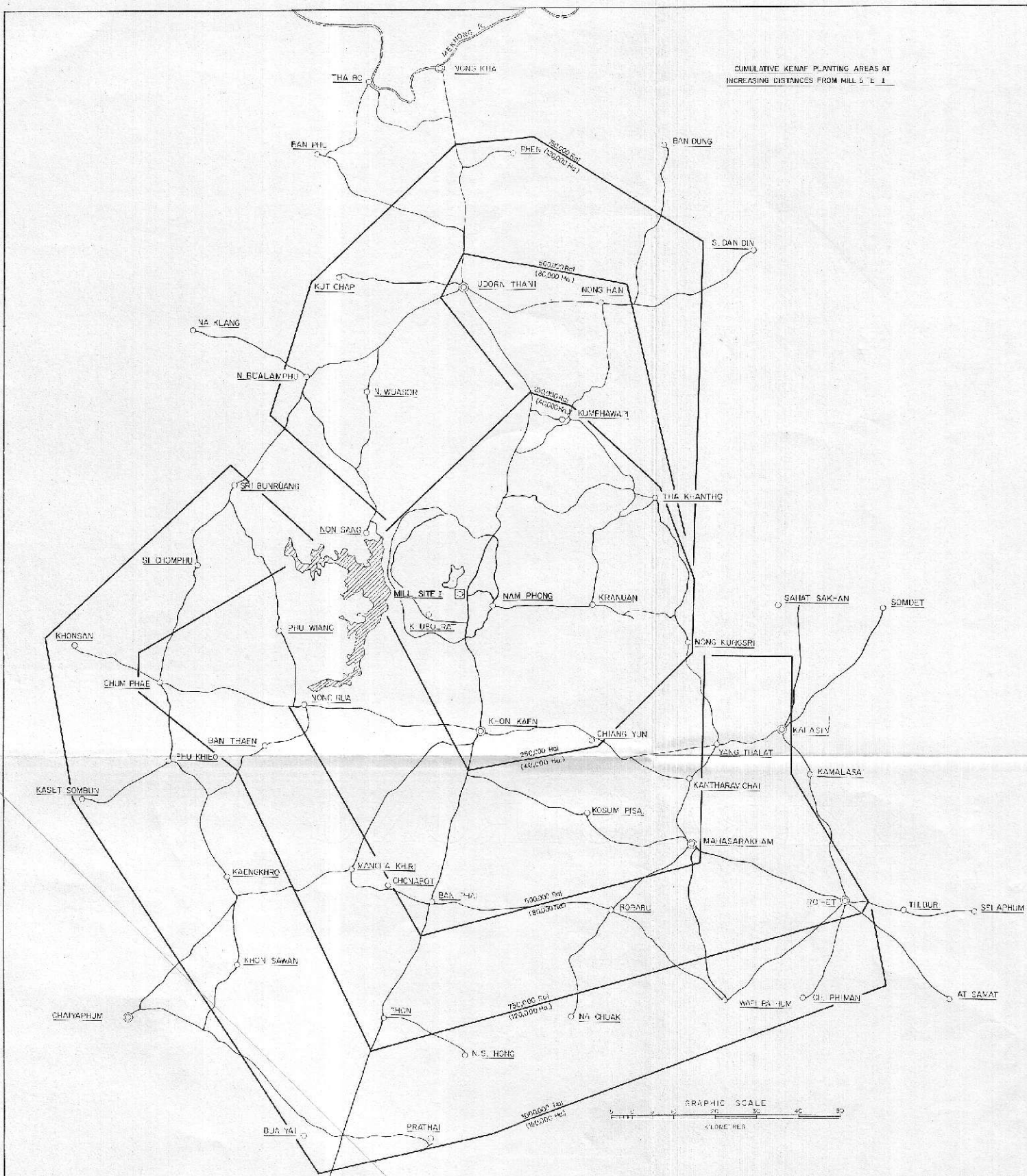
Notes: - Average Field Dry Stalk Yield = 1,200 Kg./Rai (7,500 Kg./Ha.)

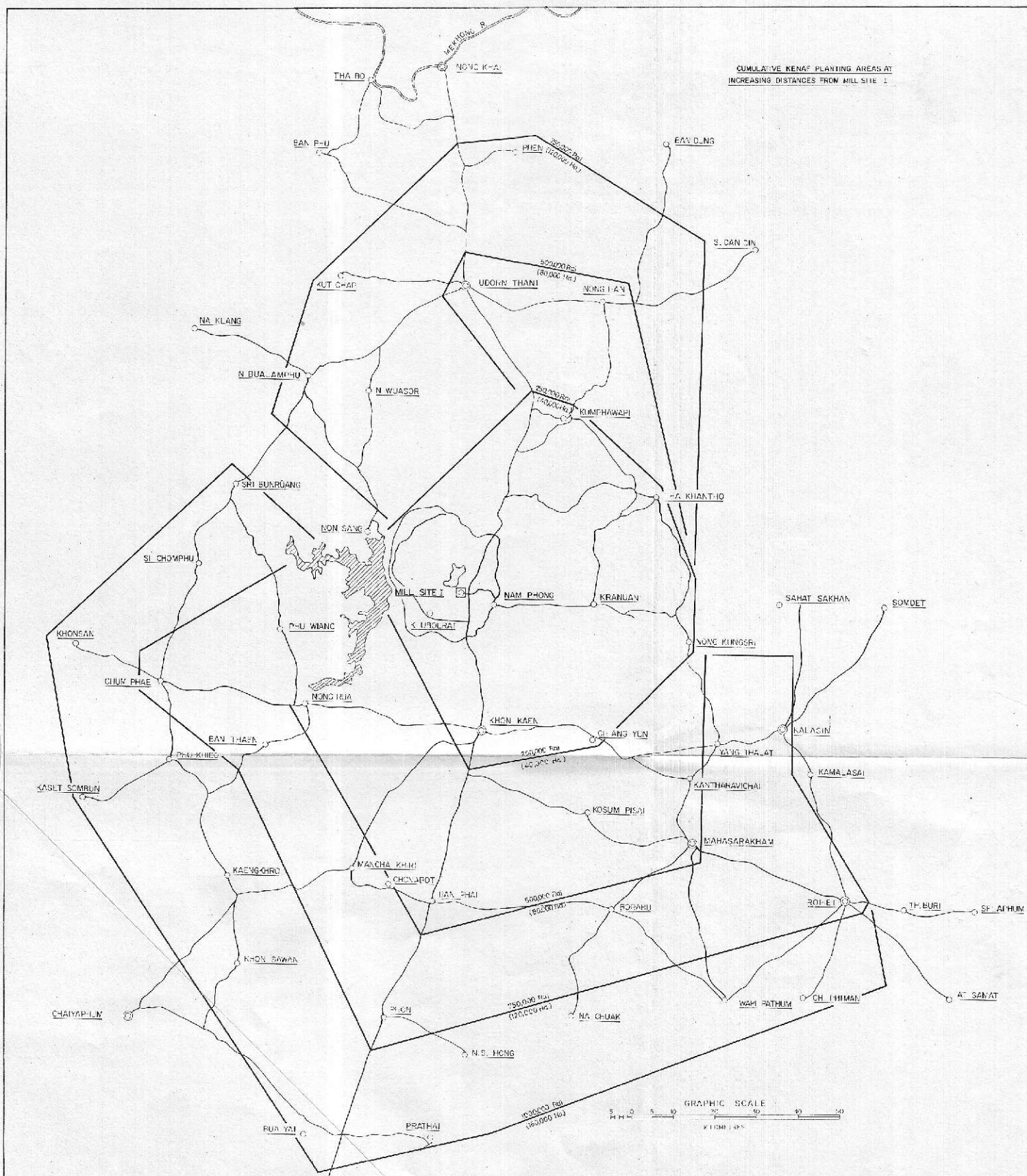
Total Raw Material Planting Area Requirements = 206,000 Tons/1.2 = 172,000 Rai (27,500 Ha.)

(1) At 20% Purchase Rate = $\frac{172,000}{0.20}$ = 860,000 Rai (137,600 Ha.) (3) At 50% Purchase Rate within 60 km. and 20% Purchase Rate beyond 60 km.

(2) At 25% Purchase Rate = $\frac{172,000}{0.25}$ = 688,000 Rai (110,100 Ha.) (4) At 75,000 Rai Production in Ubolratana Resettlement Area and 20% "Outside" Purchase Rate

Table V.8.



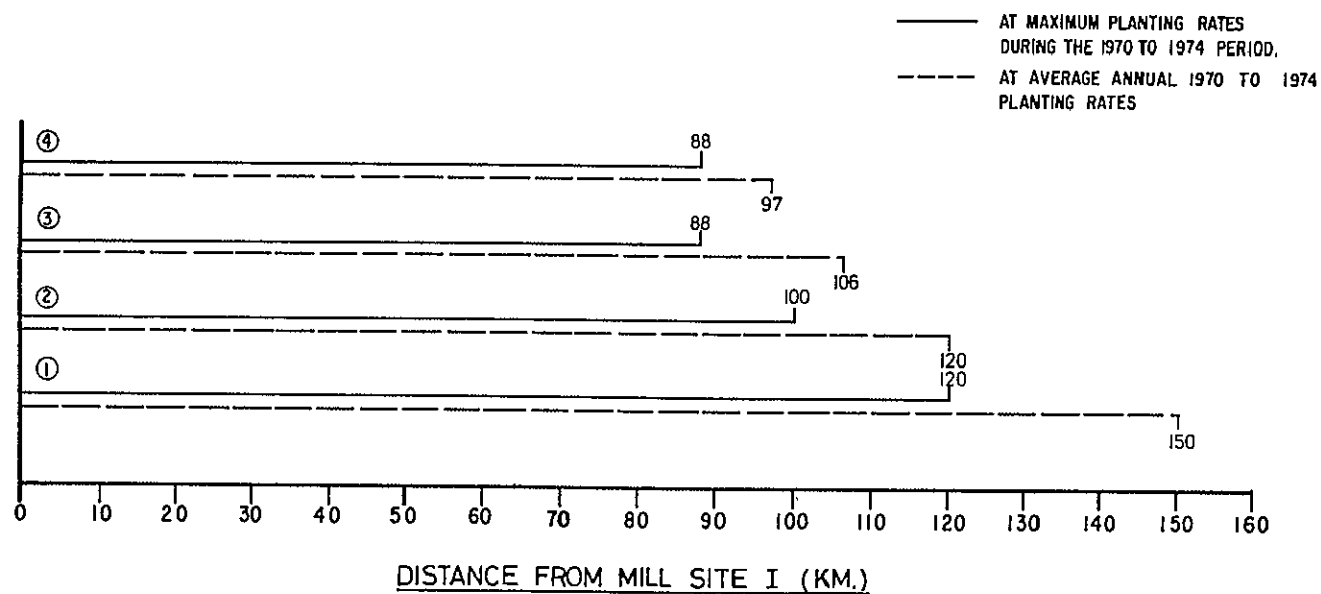


<u>1970 to 1974 Kenaf Planting Area</u>		
	<u>Average</u>	<u>Maximum</u>
(1) At 20% Stalk Purchase Rate	150 km.	120 km.
(2) At 25% Stalk Purchase Rate	120 km.	100 km.
(3) At 50% Within 60 km. and 25% Beyond 60 km. Purchase Rates	106 km.	88 km.
(4) 75,000 Rai (12,000 ha.) Production Area at Ubolratana Plus 20% "Outside" Purchase Rate	97 km.	88 km.

Fig. V.4. shows the maximum transportation distances for the above four alternatives graphically.

From the above and from Table V.8., it seems reasonable to assume that, although the stalk supply up to a maximum road distance of 160 km. from Mill Site I should be investigated, it is most likely that the mill would be able to obtain its entire requirements from a maximum road distance of 120 km. at the proposed 25 percent maximum purchase rate of available whole stalk raw material and this figure will be used for purposes of estimation in this Study.

MAXIMUM KENAF STALK TRANSPORTATION DISTANCES AT DIFFERENT STALK PURCHASING RATES



- ① AT 20% STALK PURCHASE RATE
- ② AT 25% STALK PURCHASE RATE
- ③ AT 50% STALK PURCHASE RATE WITHIN 60 KM AND 20% PURCHASE RATE BEYOND 60 KM
- ④ AT 75,000 RAI PRODUCTION IN THE UBOL RATANA RESETTLEMENT AREA AND 20% "OUTSIDE" PURCHASE RATE

Fig. V.4.

3.4. Kenaf Stalk Procurement

As stated previously, the assumed pulp mill at Site I has an annual raw material requirement of 206,000 tons of field dry kenaf stalks. The procurement of such a substantial quantity of whole stalks and their handling and shipment to the mill will require an efficient organization in order to assure a steady supply and to keep costs to a minimum. Three procurement alternatives are discussed in this section as follows:

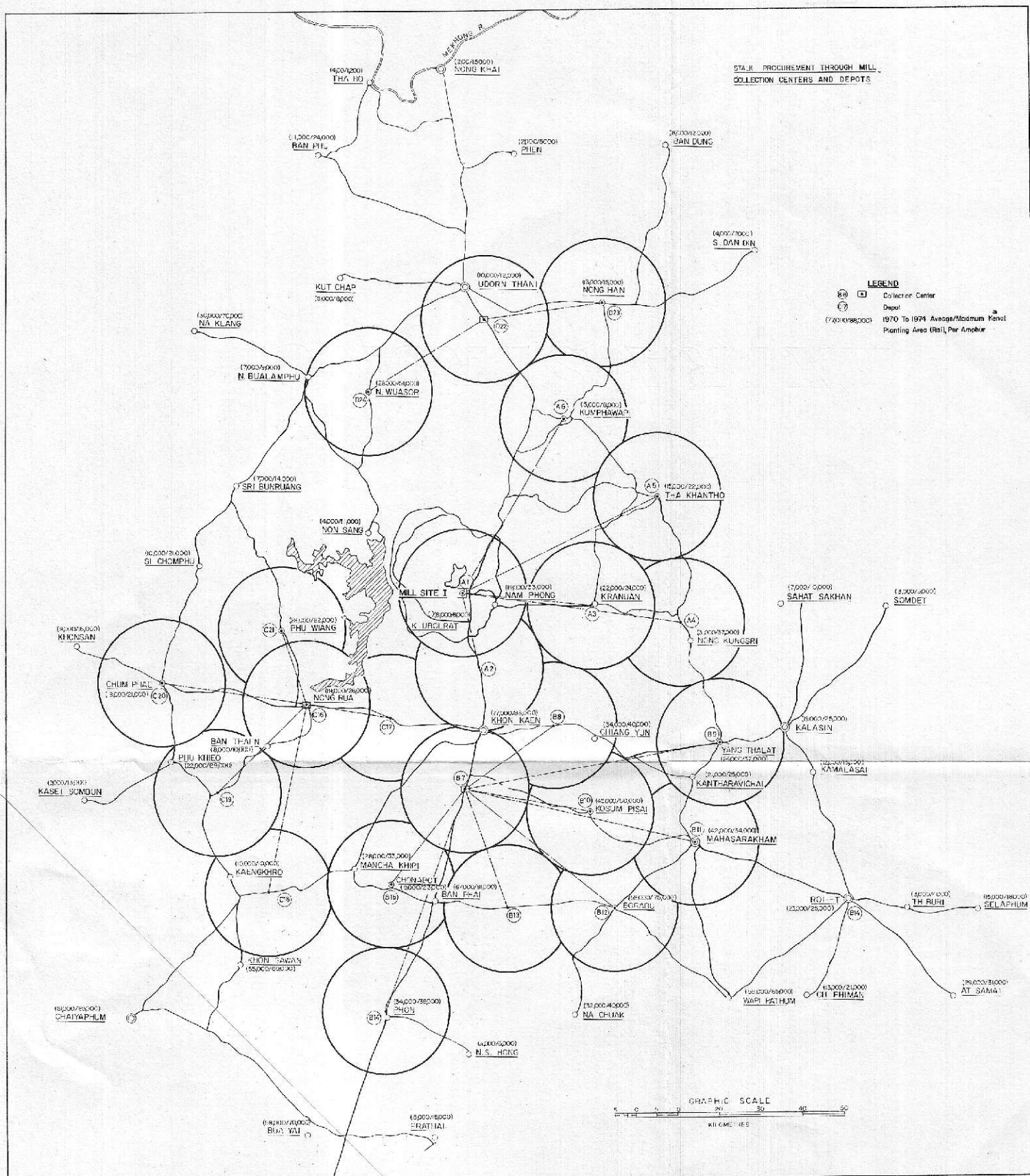
Pulp Mill Stalk Procurement Organization;
Stalk Procurement through the Baling Plants;
Stalk Procurement through Cooperatives.

Obviously, these three procurement methods can be used in combination as well as each on their own.

3.4.1. Stalk Procurement by the Mill

Under this stalk procurement system, the Whole Stalk Kenaf Pulp Mill at Site I would set up its own network of Collection Centers and Purchasing Depots. These installations would have to be established in sufficient numbers so that (a) a total of some 690,000 rai (110,100 ha.) of kenaf planting areas are covered at an average 25 percent stalk purchase rate (Table V.8.), and (b) no kenaf farmer will have to travel further than 15 km. to deliver his stalks to the nearest Collection Center/Depot, this being the distance up to which the grower can conveniently transport his stalks in his bullock cart. Based upon the average kenaf planting areas "within economic distance from Mill Site I" during the five-year period from 1970 to 1974, these conditions can be met by establishing four Collection Centers with a total of twenty satellite Depots, as shown in Plate V.3. and supported by Table V.9. It will be seen that the maximum lead distance is 120 km.

A Raw Material Controller would be made responsible for the overall purchasing operation. He would be assisted by four Collection Center Managers in charge of their respective Centers and satellite Depots. One of the Collection Centers (A1) (Plate V.3.) would be at Mill Site I itself, in fact at the mill yard, and the three other Centers would be located on the Khon Kaen/Ban Phai Road (B7), at Nong Rua (C16), and on the Nam Phong/Udon Thani Road (D22) respectively.



Stalk Procurement Through Mill Collection Centers and Depots
Mill Site I

Center Depot No.	Location	Distance from Mill Site I (km)	Kenaf Planting Area (Rai)			
			1970 to 1974		Cumulative Total	
			Average	Maximum	Average	Maximum
A1	Mill Site I	0	27,000	31,000		
A2	Nam Phong/Khon Kaen Road	18	20,000	22,000		
A3	Kranuan	32	22,000	24,000		
A4	Nong Kungsri	54	31,000	57,000		
A5	Tha Kantho	72	15,000	22,000		
A6	Kumphawapi	55	5,000	8,000	120,000	164,000
B7	Khon Kaen/Ban Phai Road	48	19,000	22,000		
B8	Khon Kaen/Chian Yung Road	49	34,000	40,000		
B9	Yang Thalot	105	26,000	32,000		
B10	Kosum Pisai	73	46,000	50,000		
B11	Mahasarakam	92	42,000	54,000		
B12	Borabu	120	56,000	75,000		
B13	Ban Phai/Borabu Road	92	34,000	41,000		
B14	Phon	106	34,000	38,000		
B15	Chonabot	88	80,000	96,000	371,000	448,000
C16	Nong Rua	79	19,000	26,000		
C17	Khon Kaen/Nong Rua Road	55	19,000	22,000		
C18	Manchakiri/Kaeng Khro Road	120	37,000	40,000		
C19	Ban Thaen/Phu Khieo Road	114	19,000	29,000		
C20	Chum Pae	113	29,000	35,000		
C21	Phu Wiang	97	28,000	62,000	151,000	214,000
D22	Nam Phong/Udorn Thani Road	75	10,000	12,000		
D23	Nong Han	95	13,000	15,000		
D24	Nong Wuasor	113	28,000	51,000	51,000	78,000
Total - Rai					693,000	904,000
- Hectare					(111,000)	(145,000)

Table V.9.

Collection Center sites have been chosen in such a manner as to afford good road connections with their satellite Depots for ease of raw material transport and supervisory control.

Quite obviously, the site/capacity of the individual purchasing Depots will vary in accordance with the kenaf planting area within a 15 km. stalk transport lead distance from their location, taking into consideration that it is assumed that only 25 percent of the total production is to be purchased. In order to economize on Depot facility installation and supervision, it might be decided to combine two or more geographically adjacent depots and to downgrade the relinquished locations into simple purchasing facilities from which the raw material would be trucked, at frequent intervals, to the nearest Depot. Similarly, the area covered by the B7 Collection Center (Plate V.3.) could be sub-divided and another Collection Center established at, say, Mahasarakam.

It is emphasized most strongly that it is considered counter-productive for the pulp mill to attempt to purchase the entire kenaf stalk crop in any specific area, or even a substantial proportion of such crop, and thus to compete outright and uncompromisingly with the traditional kenaf fiber trading channels. This is the principal reason why it is assumed that, on the average, only 25 percent of the kenaf stalks available in any one Depot's area of coverage will be purchased by these Depots. At the same time, kenaf stalk procurement is based on the assumption that the growers will transport the field dry stalks (defoliated and free of seed capsules) in their bullock carts to the nearest Depot. This is a reasonable assumption, since the Northeast kenaf farmers frequently transport their harvested stalks to the retting facilities and their retted fiber to the village buyers in this manner. In order to make such stalk transport convenient to the growers, the Depots would be located on a road and at a maximum lead distance of 15 km. from the kenaf farms.

Upon arrival at the Collection Center/Depot, the stalks brought in by the farmers would be weighed and payment made on the spot. Stalk transport between the Depots and the Collection Centers and/or the pulp mill would be done by contract truckers.

3.4.2. Stalk Procurement Through the Kenaf Baling Plants and Traders

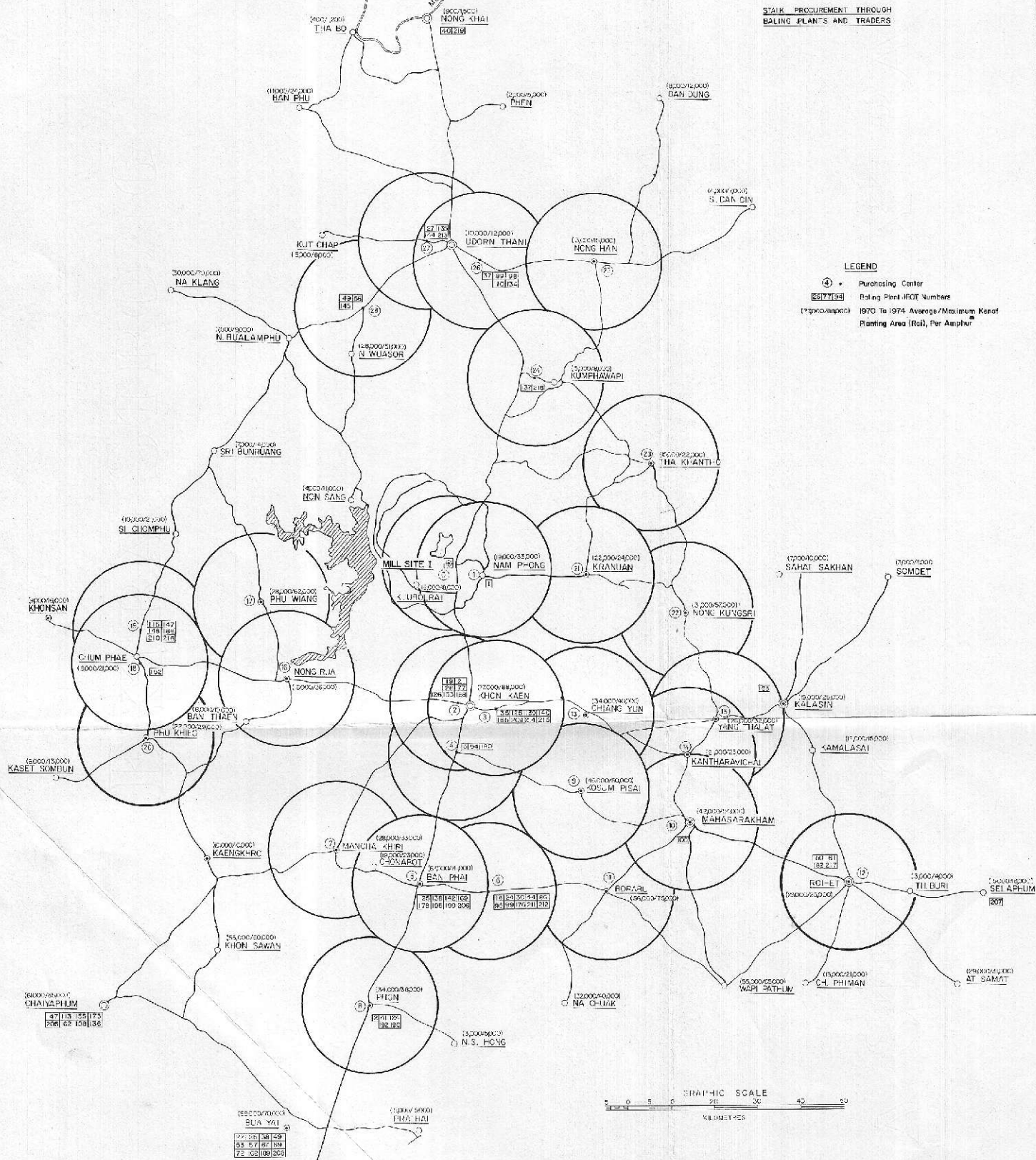
The second stalk procurement alternative would be to involve the existing kenaf baling plants and traders in the stalk purchasing operations. It is submitted that this procedure offers a number of advantages.

The traditional function of the kenaf baling plants in the Northeast is to purchase the retted fiber from the farmers, either directly or through lower level traders, to grade the fiber according to quality, cut off the butt-ends (cuttings) of the fiber bundles, and compress the graded fiber into high density bales for sale to the local bag mills or the exporters. These baling plants have their established purchasing procedures and connections in the kenaf growing area they cover. Many of them send their own trucks to the farmers' fields or at least to the nearest road head to collect the retted fiber and could do the same as far as whole stalk collection is concerned. The baling plants also dispose of storage facilities, a large part of which are unused during the off-season for retted kenaf fiber (about March to September) and which could be used for stalk storage. They are also able to bale with their existing presses at low or high density as desired - either the whole stalks or the chopped stalks, if this latter procedure should be decided upon.

The involvement of the existing baling plants would obviate the necessity for the pulp mill to establish and operate its own Collection Center/Depot organization, including land and facility purchase, construction or lease. The mill staff could then merely exercise a supervisory function. Equally and probably even more important, the mill would then not compete but rather cooperate with the balers. Vigorous and very likely effective counter-action by the established balers and traders could be anticipated if the mill were to attempt its own stalk purchases which would inevitably reduce the balers' and traders' business by at least 25 percent - and probably more as a result of the greater convenience to the farmers to sell whole stalks rather than retted fiber. On the other hand, mill stalk purchases through the balers and traders would maintain and, most likely, increase their revenues, particularly within the shorter lead distances from the mill site, and thus assure their cooperation.

There are well over 200 baling plants in Northeast Thailand (see Annex II). Those located in the kenaf production areas "within economic distance from Mill Site I" (Tables V.7. and V.8.) identified by their "JBOT Numbers" (Jute Balers of Thailand registration numbers) are shown in Plate V.4. Based upon the supporting Table V.10. and the

STALK PROCUREMENT THROUGH BALING PLANTS AND TRADERS



Stalk Procurement Through Baling Plants and Traders
Mill Site I

Center No.	Location	Distance from Mill Site I (km)	Kenaf Planting Area (Rai)			
			1970 to 1974		Cumulative Total	
			Average	Maximum	Average	Maximum
0	Mill Site I	0	8,000	8,000	8,000	8,000
1	Nam Phong	10	19,000	33,000	27,000	41,000
2	Khon Kaen I	35]	77,000	88,000	104,000	129,000
3	Khon Kaen II	38]				
4	Tha Phra	43]				
5	Ban Phai I	76]	67,000	81,000	171,000	210,000
6	Ban Phai II	88]				
7	Manchakiri	100				
8	Phon	106	34,000	38,000	233,000	281,000
9	Kosum Pisai	73	46,000	50,000	279,000	331,000
10	Mahasarakam	92	42,000	54,000	321,000	385,000
11	Borabu	120	56,000	75,000	377,000	460,000
12	Roi-Et	132	23,000	25,000	400,000	485,000
13	Chiang Yun	64	34,000	40,000	434,000	525,000
14	Kantaravichai	95	21,000	25,000	455,000	550,000
15	Yang Talat	105	26,000	32,000	481,000	582,000
16	Nong Rua	79	19,000	26,000	500,000	608,000
17	Phu Wiang	97	28,000	62,000	528,000	670,000
18	Chum Phae I	115]	18,000	21,000	546,000	691,000
19	Chum Phae II	117]				
20	Phu Khieo	132	22,000	29,000	568,000	720,000
21	Kranuan	32	22,000	24,000	590,000	744,000
22	Nong Kungsri	57	31,000	57,000	621,000	801,000
23	Tha Kantho	72	15,000	22,000	636,000	823,000
24	Khumpawapi	55	5,000	8,000	641,000	831,000
25	Nong Han	95	13,000	15,000	654,000	846,000
26	Udorn Thani I	90]	10,000	12,000	664,000	858,000
27	Udorn Thani II	90]				
28	Nong Wuasor	110	28,000	51,000	692,000	909,000
	(Hectares)				(110,700)	(145,400)

Table V.10.

cumulative kenaf planting area totals listed therein - as well as again on the assumption of 25 percent stalk purchase rates of total availability and that 15 km. is the maximum distance over which the kenaf farmer will readily transport his stalks for sale - a circle with that radius has been drawn around each baling plant or plant group "purchasing center" and supplemented by kenaf trader "purchasing centers" in those areas where baling plants do not exist within the required 15 km. maximum lead distance from the production areas. The purchasing center network in Plate V.4. then shows the locations at which stalk supply contracts would have to be entered into with established baling plants and traders to assure the required raw material supply to the mill. It will be seen that a maximum lead distance of 132 km. is involved.

However, in practice the mill would probably enter into stalk supply arrangements with a limited number of strategically located baling plants only and these plants would make their own stalk collection arrangements, as they are already doing with retted kenaf fiber. In the great majority of cases, this would mean sending their own trucks to the farms or road heads, again as in the case of retted fiber.

The mill would also have no difficulty in enlisting the balers' assistance in shipping the stalks from the baling plants to the mill site; in fact, it is anticipated that the balers would prefer contracting on a delivered mill basis for the stalk supplies. Furthermore, the balers located at a greater lead distance from the mill would absorb the additional trucking costs, as they customarily do for retted kenaf and other commodities and this would, in fact, open up practically the entire Northeast as a potential kenaf stalk supply area to the mill, rather than only the areas "within economic distance from Mill Site I" considered heretofore.

Finally, since there would be some 200 baling plants competing for the mill's very substantial stalk purchases, the mill would be in a strong bargaining position.

3.4.3. Stalk Procurement Through Cooperatives

The third stalk procurement alternative would be the organization of purchases through cooperatives or other local farmers' organizations. Ideally, this would be the preferred raw material procurement system, since it would eliminate all middleman operations and thus provide a

greater revenue to the peasant farmer kenaf producers. One potential supplier cooperative to the project sample mill at Nam Phong would, obviously, be the Ubolratana Farmers' Cooperative within whose area the proposed mill is located and it has, in fact, been assumed in Section 3.3. above that this cooperative might grow some 75,000 rai (12,000 ha.) of kenaf specifically for the mill.

It is beyond the scope of this Study to assess, in detail, the potential capabilities of the existing farmers' organizations in Northeast Thailand to provide regular kenaf stalk supplies in the 210,000 tons per year range, and the assessment of the capabilities of similar cooperatives in Laos, Cambodia and Viet-Nam will, in any case, have to be postponed until such time as the potential supply areas in those countries become accessible to the Consultants. In the meantime, it is suggested that a practical approach would include initial limited direct raw material purchases from local cooperatives in addition to more substantial purchases from the existing trading channels - or through a specifically established mill purchasing organization where no such trading channels exist - and a gradually increasing involvement of the cooperatives as they become better organized for the specific large-scale kenaf stalk supply task as a result of such mill furnished incentives as a steady market, a guaranteed and attractive purchase price, extension and other technical services, and possibly input supplies and credits.

3.4.4. Whole Stalk Baling

Field dry whole kenaf stalks are a light, bulky material (approximately 2.75 lbs./cu.ft. = 44 kg./cu.m.) and tests have shown that, under Northeast Thailand conditions, only about 1-1/3 tons of loose stalks can be loaded into the body of a 6-ton truck. Hence, in order to lower transportation (and storage) costs, the bulk of the material must be reduced prior to long distance transport.

The initial baling or, rather, bundling of the stalks should be done by the growers themselves in a manner similar to the system traditionally used for the field baling of retted kenaf fiber. After defoliation and the removal of the seed capsules from the stalk - either by hand stripping or by cutting off the stalk tips, depending upon determination, by pilot plant work, of the pulping value of the stalk tips - the stalks should be formed into bundles of reasonably uniform length and diameter, the latter by alternating the larger diameter butt ends and the tapering tip ends. These bundles should

then be tied with stripped kenaf bast strands and the strands tightened by means of two poles inserted through loops in the ends of the strands, as is done to tighten the retted kenaf fiber bales. It is reported that a bundle density of 100 to 120 kg./cu.m. can be achieved by this method, but further tests are certainly required.

The above "field bundles" could then be further compressed in the existing kenaf fiber baling presses. Preliminary tests have shown that, without the stalks being crushed, a 300 to 400 kg./cu.m. bale density can be achieved; substantially higher bale densities could be reached, if the chopping plant at the mill would not object to the stalks being crushed.

3.4.5. Whole Stalk Transport

The stalk field bundles would be transported by the growers to the individual purchasing locations (collection centers, depots, baling plants, traders' premises) in their bullock carts; from there, they would be trucked to the pulp mill. If the stalks are procured by the mill through its own purchasing organization (Section 3.4.1. above), the mill would have to contract for such transport with private truckers; if the mill decides upon stalk procurement through the traditional kenaf trading channels in the Northeast, the stalks will be delivered to the mill by the balers' own trucks or by trucks contracted by the balers, and the mill need not concern itself with transport arrangements. It is also anticipated that this latter purchase system would result in raw material cost savings to the mill, since the more distantly located balers would absorb the transportation cost differentials.

4. Chopped Stalk Kenaf Raw Material

4.1. Chopped Stalk Field Handling

As described in Section 2.8.2.2. of this Chapter V, when chopped kenaf stalk material is required for the pulp mill, the stalks could either be cut by hand into "chips" of the desired length by the peasant farmers or modified forage harvester-choppers could be employed in large mechanized operations. Under either alternative, the moisture content of the chopped material will be of paramount importance as far as subsequent handling and storage are concerned.

In Section 2.8.1. above, reference has been made to the fact that, whereas for textile fiber production the kenaf stalks must be harvested within a limited time span in order to produce optimum retted fiber quality, for subsequent pulping they can be harvested both fresh or green, i.e. at the stage at which they are harvested for textile fiber, or over-mature when they will be dried out even though they are still standing in the field.

As will be discussed in Section 4.4. below, for efficient chopped stalk storage without prohibitive quality deterioration, it is essential that the stored chips have a moisture content of less than 35 percent and, preferably, less than 25 percent.

When the kenaf is harvested at the over-mature stage or, say, from about mid-December or early January onwards under average Lower Mekong Basin climatic conditions, these moisture limitations would not be exceeded. If the stalks are harvested and chopped by hand, a low moisture content could easily be further assured by shocking the stalks in the field for a few days prior to chopping which would result in the moisture content being reduced to a "field dry" 12½ percent and thus well below the apparently critical limit. When the over-mature kenaf is harvested and chopped by mechanical equipment in a single operation, in most instances the moisture content of the chips will already be below the desired limit; if it is found that it is not, the chips could be spread evenly on the ground where, since it would then be well beyond the end of the rainy season, they would become field dry within a day or two.

The problem is entirely different with respect to the harvesting-chopping of green (fresh) stalks, i.e. stalks harvested any time prior to, say, mid-November and as early as mid-July in certain locations

and for certain H. cannabinus varieties. Not only is the moisture content of green kenaf in the 70 to 80 percent range, but the stalk chips can not be spread on the ground for drying, since the rains will not cease until late October or early November and the chips would rot on the ground both because of their being repeatedly wetted by rain and by their being in contact with the wet or even only moist soil. This is not an assumption but an established fact; even the stalk core material, from which the bast (which decomposes more readily than the woody core fraction) has been removed in mechanized kenaf field ribboning for textile fiber production, rots very quickly on the ground during the rainy season where it has been deposited by the mobile ribboning machines.

In small peasant farmer operations, the solution might be to cut the stalks and shock them in close ranks along the borders or in one corner of the field thus making most of the field readily available for a follow-up crop. Within a few days, the stalks would then dry sufficiently to preserve them until the start of the dry season when they would be chopped and the chips, if necessary, spread on the ground for additional drying.

Extensive experimentation has been carried out by the USDA with respect to the storage of "wet" kenaf chips and the reader is again referred to Chapter I, Section 2.5. As already mentioned, a 35 percent moisture content appears to be the permissible upper limit (except, obviously, if the material is to be wet stored under anaerobic conditions). All attempts to preserve the chips in storage at a higher moisture content - through the addition of preservatives, storage in evacuated cocoons or in silos, wet storage, etc. - appear to have ended in failure, either because of excessive deterioration or of excessive cost. One other alternative for large mechanized operations employing forage harvester-choppers which deliver the chips into trailers would appear to be artificial drying, preferably in the field to avoid delay and incipient deterioration or alternatively at some central locations. It seems doubtful, without further investigation, that such artificial drying would be an economic proposition.

It would appear at this time that the optimum method - and the method requiring the least investment and the least degree of research and development - would be the chopping of previously harvested and shocked kenaf stalks. This would apply to both rainy season harvested green stalks and post rainy season harvested dry stalks, the harvesting being done either manually or by row binder. The stalks could then be cut into chips by hand or by either mobile field chippers or stationary

chippers at central collection centers to which they could be transported by the farmers' bullock carts in the same manner as already described for whole stalk raw material supplies. The forage harvester-chopper would then only be used late in the season on thoroughly field dry standing stalks, say after mid-January, and that only provided a machine is developed which can efficiently deal both with kenaf planted at the close row spacings (17 to 20 cm. for H. cannabinus and 25 to 30 cm. for H. sabdariffa) which have been and will be used in the riparian countries, rather than with kenaf planted at 80 cm. or more inter-row spacings as adopted under the U.S. kenaf for paper pulp development program, as well as with stalks up to 12 to 15 ft. (3.60 m. to 4.50 m.) high. It appears likely that sugar cane harvesting equipment could easily be adapted for that purpose.

4.2. Chopped Stalk Baling

The desirability or otherwise of stalk chip baling is a question of the mechanics, convenience and economics of chip transport and mill yard storage.

If (a) the distance between the production area/collection center and the pulp mill is not great so that the transport of the low bulk density loose chips (4.5 lbs./cu.ft. - 72 kg./cu.m.) is not too costly, and (b) the chips will be pulped during the dry season so that elaborate measures to protect the bulk stored chips against the rain in the mill yard are not required, it would probably be more straight-forward and economic to ship the chopped stalks in bulk. Otherwise, the baling of the stalk chips and bale transport will clearly prove to be more efficient and more economic under Lower Mekong Basin conditions - although not necessarily in the developed countries - particularly in view of the probably large distances involved, the available trucking equipment and the limitations imposed on increasing truck capacities, the possible necessity or desirability of repeated handling of the bales, etc.

It is submitted that the presses manufactured in Thailand and installed in the kenaf fiber baling plants in the Northeast of the country as well as in several countries overseas are suitable for the efficient baling of kenaf stalk chips. Retted kenaf textile fiber in Thailand is compressed into bales of:

$$49 \times 18\frac{1}{2} \times 18\frac{1}{2} \text{ in. } (124.5 \times 47 \times 47 \text{ cm.}) = 9.7 \text{ cu.ft. } (0.275 \text{ cu.m.}).$$

Since 5.5 bales make up 1 long ton (2,240 lbs.), the weight per bale is:

$$2,240 \text{ lbs.} / 5.5 = 407 \text{ lbs. } (181 \text{ kgs.}).$$

Then, the bulk density is:

$$\begin{aligned} 407 / 9.7 &= 42 \text{ lbs./cu.ft.} = 53.3 \text{ cu.ft./metric ton} \\ (181 / 0.275 &= 658 \text{ kg./cu.m.} = 1.52 \text{ cu.m./metric ton}). \end{aligned}$$

Rounded off, the bulk density is then assumed to be 40 lbs./cu.ft.
= $40 \times 16 = 640$ kg./cu.m. for field dry retted kenaf fiber.

No tests have yet been made with the baling of chopped kenaf stalks in the Thai baling presses. For purposes of this Study it is assumed that, because of the lesser specific weight and the lesser pliability of stalk chips as compared to retted fiber, field dry chip bales will have a 33-1/3 percent lesser bulk density than fiber bales

or:

27 lbs./cu.ft. (427 kg./cu.m.).

The actual production of chip bales in the Thai kenaf fiber presses should be a simple matter, in fact simpler than fiber baling. The chips could be loaded into the baling chamber by shovel or bucket or similar implement. It is anticipated that, as a result of the remaining chip moisture, the compression of the material will form a solid bale which will not require any wrapping except for the standard rope (or, say, kenaf bast ribbon) ties, and that it will withstand repeated and reasonably rough handling without breaking at the edges. The bales could then be transported, handled, stacked and unstacked in the same manner as kenaf fiber bales - or any other bales of similar weights and dimensions for that matter.

In Northeast Thailand, the existing baling plants would obviously be used for stalk chip baling, a sufficient number of such suitably located plants then automatically becoming collection centers. Baling press equipped collection centers would have to be specifically established in the kenaf for paper pulp production areas in Laos, Cambodia and Viet-Nam.

4.3. Chopped Stalk Transport

The arguments governing the decision as to whether the chopped kenaf stalk material should be shipped in bulk or in bales have been discussed in the last foregoing section. Here, it is once again emphasized that developing country conditions, such as would apply to any kenaf for paper pulp program in the riparian countries, drastically differ from those in the industrialized nations and, specifically, from those underlying the United States development program. Almost complete mechanization, such as is essential to the economic viability of kenaf for paper pulp production in, say, the United States is neither necessary nor, in fact, desired in the tropics where the Governments wish to emphasize the expansion of employment opportunities for the largely rural, unskilled and low-cost labor force. In view of these and the other considerations discussed in this section, it is felt that, ultimately, most of any chopped kenaf stalk material produced for subsequent conversion into paper pulp will be shipped in bale form.

One of the major factors militating against the bulk shipment of kenaf stalk chips is their low bulk density (4.5 lbs./cu.ft. - 72 kg./cu.m.) and the limited capacity, by volume, of the trucks operating in the Basin area. Although an extensive network of excellent macadam surfaced all-weather roads exists in the region, they are mostly not designed to accommodate large capacity truck-trailers or trucks and trailers, and 10-ton trucks ("ten-wheelers") are the largest standard transportation equipment commonly used. In addition, smaller 6-ton or even 4-ton trucks must be used on many of the feeder roads. The body dimensions of both the 6-ton and 10-ton trucks are 5.00 m. long by 2.40 m. wide by 2.50 m. high (with built-up sides) or 30 cu.m. Hence, at a bulk density of 72 kg./cu.m. for loose kenaf stalk chips, such trucks can carry only 2.16 tons of bulk material. Bulk shipment of stalk chips would also require some type of mechanical loading and unloading equipment (for the trucks, silos or other collection center or mill yard storage facilities), unless they are to be shovelled into and out of these facilities by hand which would probably be impractical in view of the volumes involved; and the bulk (and bulky) material would have to be carefully protected against moisture so as to avoid excessive quality loss.

On the other hand, once stalk chips are high-density baled, the bales can be handled repeatedly if required, in the traditional manner, probably most frequently by hand at the depots and collection centers and, at most, by lift trucks or overhead cranes at the mill yard, where it is again pointed out that bales of the size and weight as would be

produced by the available standard baling presses are traditionally being manually handled and stacked to considerable heights. In view of the comparatively low cost of land, it seems unlikely that high-lift mobile cranes would be used, such as those employed in certain baled sugarcane bagasse mill yard storage operations in the United States and elsewhere. The baled material could be protected more efficiently and more economically against moisture, both because of its lesser volume and its greater density inside the bale which prevents water percolation; and a truck could carry its rated capacity of chip bales as a result of their greater bulk density, approximately 80 cu.ft./ton (27 lbs./cu.ft. = 427 kg./cu.m.). In fact, with the 30 cu.m. truck body capacity of a standard "10-ton" truck, it could (and probably would) carry close to 13 tons of baled stalk chips.

5. Kenaf Bast Ribbon Raw Material

5.1. Kenaf Ribbon Raw Material Requirements

Referring again to Chapter I, Section 7., of this Study, kenaf bast ribbon raw material will be converted into bast ribbon pulp by the mill, the selected output of such a mill, for purposes of this Study, is 70,000 air dry metric tons (ADMT) per year of bleached pulp, and it is assumed that the bleached pulp recovery rate from bast ribbon raw material amounts to 45 percent. The 70,000 ADMT/year kenaf bast ribbon pulp mill will then require 160,000 FDMT/year of kenaf bast ribbon or, on the assumption of a 12½ percent moisture content in the FD ribbon, 140,000 oven dry metric tons (ODMT) annually.

As discussed in Section 3.1. of this present Chapter V, this Study assumes that the model mills at Sites I and II respectively are both designed to process either kenaf whole stalk or bast ribbon raw material as well as any blend of these two. However, in order to avoid duplication, whole stalk kenaf raw material production and procurement has been described in detail in Section 3. above with respect to Mill Site I and bast ribbon production and procurement will be discussed with similar emphasis in this Section 5, where the reader is again reminded that this raw material type selection for a specific model mill is purely arbitrary - as was the assumption that the pulp mill at Site I will use only H. sabdariffa whole stalk raw material - and that, in both instances, the types of raw material are interchangeable as well as transferable to the potential pulp mill Sites III, IV, V and VI, and that a mixture of both whole stalk and bast ribbon is a further raw material alternative.

5.2. Kenaf Ribbon Yield per Unit Area

Whereas the Consultants must rely on outside sources - the ASRCT with regard to H. sabdariffa and, principally, the USDA with regard to H. cannabinus - as far as kenaf whole stalk yields are concerned, this is not the case with respect to kenaf ribbon yields, at least not ribbon yields of H. cannabinus, since the Consultants have been closely associated with kenaf ribbon production for textile fiber processing for many years. As discussed in Chapter III, Section 3.2., almost all Western Hemisphere kenaf is ribboned after harvesting and prior to retting for conversion into textile fiber; the ribboning process itself is described in Section 2.8.2.3. of this present Chapter V.

Retted, field dry kenaf (textile) fiber yields of H. cannabinus under medium to favorable soil and climate conditions range from a low of some 2,100 lbs./acre (1,850 kg./ha.) to a high of about 2,800 lbs./acre (3,180 kg./ha.). Weight losses during retting - i.e. the losses in weight resulting from the decomposition of the vegetable matter surrounding the fiber in the bast ribbon - may vary from as little as 22 percent to as high as 45 percent, but generally average about 34 percent. Hence, ribbon yields per unit area will vary from a low of about

$$2,100/0.66 = 3,180 \text{ lbs./acre} = 3,600 \text{ kg./ha.}$$

to a high of approximately

$$2,800/0.66 = 4,240 \text{ lbs./acre} = 4,800 \text{ kg./ha.}$$

These ribbon yield ranges for H. cannabinus (3.60 to 4.80 FDMT/ha.) are listed in the "Ribbon Yield" column in Table I.17. (Chapter I, Section 7.1.2.). They do, indeed, correspond to ribbon yields obtained in actual field operations for Western Hemisphere kenaf in numerous countries, particularly in Latin America and Africa. As will be seen in Table I.17., they represent 24 percent of the whole stalk yields established in Section 3.2. of this present Chapter V. This percentage figure is rather lower than generally assumed, a circumstance which emphasizes the need of further research on the production of both kenaf whole stalk and bast ribbon raw material specifically for conversion into paper pulp.

No field data on H. sabdariffa ribbon yields are available, since this South Asian kenaf species is, traditionally, always retted in the stalk for textile fiber production, rather than being ribboned prior to retting. Hence, the Consultants can, at this time, only assume that the percentage content of bast ribbon in the whole stalk of H. sabdariffa is similar to that of H. cannabinus. At 24 percent ribbon content, this results in the ribbon yield range of 1.80 to 2.25 FDMT/ha. shown in Table I.17.

In order to check on the probability of the assumed H. sabdariffa ribbon yield range, the ribbon yield figures are converted into retted fiber yields by multiplying them by a factor of 0.66 (34 percent retting loss). This results in a retted fiber yield range of 1,190 kg./ha. (475 kg./acre; 190 kg./rai) to 1,485 kg./ha. (595 kg./acre, 240 kg./rai). Actual retted fiber yields in Northeast Thailand are presently somewhat lower (see Chapter II, Section 5.2., Table II.11.), but have indeed fluctuated between 190 and 240 kg./rai in the recent past. It seems, therefore, reasonable to assume that from 1.80 and 2.25 FDMT/ha. of H. sabdariffa ribbon will indeed be obtainable under any future kenaf for paper pulp development program in the Lower Mekong Basin.

5.3. Kenaf Ribbon Supply Area Parameters

Reference is again made to Chapter I, Section 6., where it is indicated that bast ribbon supplies are given priority with regard to Mill Site II east of Ubon Ratchathani; whole stalk kenaf raw material supplies have already been discussed in detail in Section 3.3. of this Chapter V. It is emphasized once more that this is done only to avoid duplication of raw material supply discussions and that, for purposes of this Study, the model mills at Sites I and II are both designed to process either whole stalk or bast ribbon raw material and/or any blend of these two raw materials.

In Section 3.3. of this Chapter V, it was assumed that kenaf whole stalk raw material could be trucked economically to the mill site from a distance of up to 160 km. Such economic transportation distance is substantially greater for kenaf ribbon, since:

- (a) A higher percentage of bleached pulp is produced from ribbon than from whole stalks, i.e. 45 percent vs. 35 percent (Chapter VII, Section 3.), thus increasing the raw material value per unit weight to the mill by 30 percent; and
- (b) The bulk density of the ribbon material is greater than that of whole stalk material, even baled chopped whole stalks - bulk density of baled chopped whole stalks = 427 kg./cu.m. (Chapter V, Section 4.2.); bulk density of baled ribbon = 576 kg./cu.m. (Chapter V, Section 5.5.) - thus reducing the transportation cost per unit weight by some 35 percent.

The combination of these two factors permits an increase in the economic transportation distance for bast ribbon of about 70 percent, or from 160 km. for whole stalks to 270 km. for bast ribbon. Assuming a 25 percent greater road than straight line distance, a circle with a radius of 200 km. has then been drawn with Mill Site II at its center (Plate V.5.), and it is presumed that, from the standpoint of transportation economics, the requirements of the mill would have to be covered from kenaf plantings within that circle.

It will be seen that the potential ribbon supply area includes not only some 50 percent of the traditional kenaf production area in Northeast Thailand but also all or part of the Provinces of Savannakhet, Saravane, Wapikhamthong, Champassac, Sedone, Attapeu and Sithandone in Laos, and of the Provinces of Oddar Meanchey, Siemreap, Preah Vihear and Stung Treng in Cambodia. Although there has been no large scale kenaf production in the listed provinces in Laos and Cambodia in the

A map of the Udon Ratchathani area in Northeast Thailand. The map shows the following provinces and cities:

- Provinces:** Nakhon Phanom, Savannakhet, Surin, Si Sa Ket, Udon Ratchathani, Chanthaburi, Saravane, Sattap, Oddar Meanchey, Preah Vihear, Siem Reap, Stung Treng, and Ratan.
- Cities:** Nakhon Phanom, Savannakhet, Kalasin, Maha Rakham, Roi Et, Udon Ratchathani, Chanthaburi, Saravane, Sattap, Oddar Meanchey, Preah Vihear, Siem Reap, Stung Treng, and Ratan.
- Scale:** A scale bar indicates 200 km.
- Other features:** The map includes a grid of latitude and longitude lines, a compass rose, and a legend.

past, Plate IV.1. (Chapter IV, Section 1.) shows that, with the exception of the Province of Wapikhamthong in Laos, the areas covered by the 200 km. radius circle in both these countries are indeed potentially suitable for kenaf production. Hence, from the raw material supply point of view, a long fiber kenaf pulp mill located at Site II could well be considered a regional Cambodian-Lao-Thai project - as could, incidentally, a long fiber pulp mill located at Site III at Stung Treng which would, in addition, include the Provinces of Darlac, Pleiku and Kontum in Viet-Nam in its supply area.

Table V.11. lists the kenaf producing Changwats (Provinces) in Northeast Thailand included in the ribbon supply parameter in order of the road distance of their province capitals from Mill Site II; it also lists each Changwat's annual kenaf planting area for the 1967 to 1974 period and the average and maximum planting areas during that same period. (Note: It was not considered necessary, at this time, to break down the foregoing planting area information by Amphur, as has been done in the case of the Pulp Mill Site I whole stalk raw material supply area; such detailed breakdown can readily be prepared subsequently following the format of the Site I sample.)

5.3.1. South Asian Kenaf Ribbon Supplies

In Table I.17. (Chapter I, Section 7.2.2.), it has been estimated that a maximum of 555,500 rai (89,000 ha.) of H. sabdariffa planting area would be required to supply the kenaf ribbon requirements of a 70,000 ADMT/year kenaf bast ribbon pulp mill. Also, as in the case of the proposed mill at Site I, it is again assumed that the mill at Site II would not attempt to purchase more than 25 percent, on the average, of the available kenaf in the Northeast, so as to avoid opposition from the bag mills and the kenaf balers and exporters. Hence, a total H. sabdariffa planting area of $555,500 \times 4 = 2,222,000$ rai (353,500 ha.) would be required. Referring then to Table V.11., it will be seen that the average annual production area during the 1967 to 1974 period in the eight Northeastern Changwats within a 200 km. straight line radius from Mill Site II was sufficient to satisfy only a little more than 50 percent of the ribbon raw material requirements of the mill (and that even the maximum annual planting area fell short in that respect), and that some 960,000 rai (154,000 ha.) in additional planting area would be required, under Northeast conditions, to make up the deficit.

Kenaf Planting Areas, by Changwat, Within Economic Ribbon Transportation Distance
from Mill Site II

Changwat	Distance (km) (2)	Annual Kenaf Planting Area (Rai)								1967 to 1974	
		1967	1968	1969	1970	1971	1972	1973	1974	Average	Maximum
Ubon Ratchthani (1)	30	261,229	78,378	266,000	151,942	222,896	228,027	418,335	299,428	240,800	418,300
Sisaket	93	56,524	211,280	74,134	94,881	118,586	187,613	191,859	185,613	140,100	191,900
Surin	192	62,347	12,515	47,865	90,126	132,435	172,671	190,467	156,187	108,100	190,500
Roi Et	200	168,168	76,454	91,621	140,719	153,283	108,484	132,544	139,347	126,300	168,200
Mahasarakam	240	349,819	186,938	378,431	313,588	383,442	368,168	410,026	299,225	336,200	410,000
Buriram	245	57,218	18,880	93,552	145,772	201,833	217,689	336,940	144,109	152,000	337,000
Kalasin	283	140,085	54,838	102,892	75,203	118,237	158,761	161,501	145,904	119,700	161,500
Nakhon Phanom	300	58,068	38,434	40,545	24,461	28,333	29,489	57,462	32,675	38,700	58,100
TOTAL: Rai		1,153,458	677,627	1,095,040	1,036,692	1,359,045	1,470,902	1,899,134	1,402,488	1,261,900	1,935,500
Hectare		(184,553)	(108,420)	(175,206)	(165,870)	(217,447)	(235,344)	(303,861)	(224,398)	(201,900)	(309,700)

Notes: (1) Incl. Yasothon
(2) Distance from Mill Site II to Provincial Capital

The most obvious manner in which to overcome this "shortfall" would be to promote kenaf production in the neighboring provinces in Laos and Cambodia, within the supply area circle. Since it has been assumed that there exists no large scale competition from other sources for kenaf in those two countries, the entire output of any new production areas could be reserved to the pulp mill, so that only an additional 240,000 rai (38,400 ha.) of H. sabdariffa planting would be required jointly in Laos and Cambodia.

Other alternatives leading to greater South Asian kenaf ribbon supplies would be:

- A (likely) increase in H. sabdariffa bast ribbon yield from 0.288 to 0.360 FDMT/rai (1.80 to 2.25 FDMT/ha.) as a result of pulp mill sponsored improved seed production and demonstration and extension services which would reduce the total supply area requirement to some 1,776,000 rai (284,000 ha.) (see Table I.17.);
- An increase in planting areas in the eight Changwats in the Northeast closest to the mill site as a result of the price incentives offered by the mill and the greater ease of ribbon as compared to retted fiber production;
- A specific increase in kenaf production, exclusively for the pulp mill, in the seven Resettlement Areas of the Department of Public Welfare located at Mukdahan (Nakorn Phanom), Prueyai and Huekla (Sisaket), Prasart (Surin), Ban Kruad (Buriram), and Lamdomnoi and Lamdomyai (Ubon Ratchathani);
- The fact that, in practice, the entire Northeast - rather than only the eight Changwats closest to the mill site - would serve as ribbon supply area and that the mill would thus be able to draw on an average annual planting area of 2.4 million rai (384,000 ha.) (see Fig. II.1.), rather than on only approximately one-half of that area (see Section 5.6. below).

5.3.2. Western Hemisphere Kenaf Ribbon Supplies

The total planting area upon which the kenaf bast ribbon pulp mill at the proposed Site II would have to draw would be greatly reduced, if the South Asian kenaf (H. sabdariffa) could be substituted by Western Hemisphere kenaf (H. cannabinus), since the latter produces, under adequate conditions, approximately twice the stalk and ribbon yield.

As shown in Table I.17., the total supply area requirement, even on the assumption of low bast ribbon yields, would then be reduced from 555,500 to 278,000 rai (89,000 to 44,500 ha.). Under Northeast Thailand conditions, where it is assumed that the pulp mill would purchase only 25 percent of the available crop, this would mean a reduction from 2,222,000 to 1,112,000 rai (355,500 to 178,000 ha.).

In Chapter IV, Section 5., it was assumed that, based upon the General Soil Map (Plate IV.1.), substantial potential H. cannabinus production areas exist in a number of provinces in the Northeast, including the following provinces which are located within a 200 km. straight line radius from Mill Site II and which are listed here together with their average 1967 to 1974 average annual planting areas:

<u>Province</u>	<u>Planting Area</u>
Ubon Ratchathani	240,800 Rai
Sisaket	140,100 Rai
Surin	108,100 Rai
Buriram	152,000 Rai
Nakorn Phanom	<u>38,700 Rai</u>
Total	679,700 Rai (109,000 Ha.)

Assuming further that some 50 percent of the above total area would be suitable for H. cannabinus production and that 50 percent of this Western Hemisphere kenaf crop would be purchased by the pulp mill, the equivalent of some 170,000 rai (27,200 ha.) of H. cannabinus planting area would become available to the mill in the Northeast alone. The balance of 108,000 rai (17,300 ha.) would have to be secured from H. cannabinus plantings in Laos and Cambodia. Since all of the potential kenaf production areas south of Thakhek in Laos as well as most of such areas in northern Cambodia lie within a 200 km. straight line radius from Mill Site II, since these areas include at least 50 percent of superior soil suitable for H. cannabinus production, and since the entire Laos and Cambodia kenaf production could be reserved for the pulp mill (see Chapter I, Section 7.2.2.), there should be no difficulty in securing the required balance from these two countries.

The reader is here reminded that the bast ribbon from both H. sabdariffa and H. cannabinus is equally suitable for the manufacture of long fiber paper pulp and that, unless it is desired to include Laos and/or Cambodia in the raw material supply area, there would exist no difficulty in making up the shortfall of H. cannabinus bast ribbon with H. sabdariffa bast ribbon exclusively from Northeast Thailand plantings.

5.4. Kenaf Ribbon Processing

Kenaf ribbon production has already been described in Section 2.8.2.3. of this Chapter V. As explained in that section, it has been used in commercial production of kenaf textile fiber for at least 30 years, particularly in Africa and Latin America. It is, thus, by no means in the experimental stage and it can be applied without modification to the production of bast ribbon pulp. In fact, the only major difference between kenaf ribbon production for textile fiber and for paper pulp is that, whereas for textile fiber production the ribbon must be retted (submerged in water) and the resulting fiber washed, dried and graded, for paper pulp production the ribbon is delivered to the mill as it is recovered in the field.

So far, there has never been any demand for fully mechanized field harvesting/ribboning operations for kenaf textile fiber production since the crop is always grown in the developing countries of the tropics where low cost labor is usually abundantly available and where, in fact, it is desirable to create employment for such labor, and it is anticipated that kenaf for paper pulp will be produced largely in the same manner, probably with the help of the field ribboning machines mentioned above, although larger raw material volumes are, of course, involved in the case of a pulp mill compared to a bag and hessian mill. Nevertheless, if kenaf for paper pulp is to be produced on large-scale commercial plantations, all the basic knowledge exists for the prompt development of fully mechanized field equipment which would combine the features of the established ribboning machines with those of the modern sugar cane harvesting equipment, where the extent of desired and/or desirable mechanization again depends upon the location of the kenaf production operation.

5.5. Kenaf Ribbon Drying and Baling

As explained in the foregoing, kenaf stalk bast stripping (ribboning) whether by hand or by machine, must be done while the stalks are still fresh or "green". In order to avoid deterioration, the green ribbon must then be dried before it is handled further.

A substantial percentage of stalk ribboning will have to be done while the rainy season is still in progress; during that period, the ribbon will have to be spread on wood or bamboo pole lines for drying, much as is done already for retted fiber drying. No damage will be done to the ribbon by repeated wetting by rain and drying at the sun on these lines. Once the rainy season is over and the ground has dried out, the ribbon can be dried by simply spreading it on the ground and turning it over once or twice. The required drying time will, of course, depend on the weather; when this is warm and sunny, the ribbon will become "field dry" ($12\frac{1}{2}$ percent moisture content) in a day or two.

After drying, the ribbon should be field baled for further transport. One possible ribbon field bale would be a duplication of the traditional Northeast Thailand retted kenaf fiber "drum" such as the farmers of that region are used to preparing for sale to the village dealer or the baling plant. Another method would be to use an open-topped wooden box with one hinged side into which the ribbon bundles are folded and pressed down by a man walking on them; the finished bale is tied with strands of ribbon and removed from the box through the hinged side. A standard field baling box is 1 m. long x 0.65 m. high x 0.65 m. wide or 0.42 cu.m. and will hold some 60 kg. of compressed ribbon which is equivalent to a bale density of approximately 140 kg./cu.m. (8.75 lbs./cu.ft.) or 7.14 cu.m./metric ton (252 cu.ft./metric ton).

Again, the above field handling methods are well established standard practice, either as applied to kenaf ribbon for textile fiber production in Latin America, Africa, etc., or to jute and kenaf textile fiber production in Southeast Asia.

The ribbon field bales would then be transported to depots or collection centers, either by the small farmers' bullock carts or by trucks in centralized operations.

Whilst the bulk density of field baled ribbon is adequate for farm storage, it would be too costly to transport the ribbon thus loosely baled over long distances to the pulp mill or to store it in

such field bales at the mill. Hence, as in the case of chopped stalk material, the dry ribbon should be further compressed in the presses already installed in the more than 200 kenaf baling plants in Northeast Thailand or in similar presses to be installed in central collection facilities in new kenaf for paper pulp production areas in Laos, Cambodia and Viet-Nam. As explained in Section 4.2. of this Chapter V (Chopped Stalk Baling), retted kenaf textile fiber in Thailand is compressed into a bulk density of 640 kg./cu.m. (40 lbs./cu.ft.). Although it is likely that kenaf ribbon could be compressed to the same bulk density without any modification of the standard presses, to be conservative it is assumed that kenaf ribbon bales will have some 10 percent less bulk density than retted fiber bales, since ribbon is somewhat more bulky and less flexible, or 576 kg./cu.m. (36 lbs./cu.ft.) equivalent to 1.74 cu.m./metric ton (61.2 cu.ft./metric ton).

5.6. Kenaf Ribbon Procurement

As in the case of whole kenaf stalk procurement for the whole stalk kenaf pulp mill, three basic raw material procurement alternatives are available to secure the kenaf ribbon raw material requirements of the kenaf bast ribbon pulp mill assumed, for purposes of this Study, to be located at Mill Site II. These three alternatives are:

Pulp Mill Ribbon Procurement Organization;
Ribbon Procurement through the Baling Plants;
Ribbon Procurement through Cooperatives.

Again, the three procurement methods can be combined or each used on its own.

Whereas it has been estimated that a whole stalk kenaf pulp mill assumed to be located at Mill Site I could procure its 206,000 FDMT of whole or chopped kenaf stalks within a maximum road distance of 120 to 130 km. (Fig. V.4., Section V.3.3.), it has been projected in the foregoing Section 5.3. that the assumed kenaf bast ribbon pulp mill at Site II would have to extend its purchasing operations over more than twice that road distance to secure its annual requirements of 160,000 FDMT of bast ribbon, i.e. to up to about 270 km. from the mill site. Furthermore, on the assumption that again only 25 percent of the available kenaf raw material would be purchased by the pulp mill within the Northeast in order to avoid competing excessively with the bag mills and fiber exporters* for the available supplies, there would be a shortfall of some 69,000 tons of ribbon availability in the eight Changwats within 270 km. road distance (or within a 200 km. straight line radius) from Mill Site II in the case of H. sabdariffa ribbon, which would have to be procured from the neighboring potential kenaf producing areas in Laos and Cambodia within such 270 km. maximum road distance; and a shortfall of approximately 62,000 FDMT in the case of H. cannabinus ribbon, again to be procured in the bordering production areas in Laos and Cambodia.

From the foregoing it will be seen that the kenaf bast ribbon pulp mill's raw material purchases will have to be made in a very much greater area than those of the mixed fiber pulp mill and that, if the mill was to establish a sufficient number of depots and collection centers of its own to assure the producers that, as in the case of whole stalk sales, they would not have to travel more than 15 km. to dispose of their ribbon, the capital and operating costs of such a pulp mill operated purchasing organization would obviously become excessive. It is, therefore, argued that kenaf bast ribbon procurement through the mill's own

purchasing organization is not an economic proposition and that, even more so than in the case of whole or chopped kenaf stalk purchases, ribbon procurement through the existing kenaf baling plants and, in Laos and Cambodia, through established produce traders is the most efficient procedure.

Kenaf bast ribbon purchases would resemble the kenaf balers' traditional retted kenaf fiber purchases very closely indeed. As explained in Section 3.4.2. of this Chapter V, the balers have their long established retted fiber purchasing procedures in the kenaf growing areas including, in many cases, the dispatch of their own trucks to the fields or nearby road heads. The high density baling of bast ribbon is identical to retted fiber baling but does not require preliminary root cutting, hackling and grading, as in the case of retted kenaf fiber. Finally, the baling plants dispose of storage facilities which are only little used during part of the year and could accommodate a substantial portion of the pulp mill's overall annual ribbon requirements thus relieving the pressure on the mill's own storage facilities.

Again as in the case of whole or chopped whole kenaf stalk procurement, the participation of the established balers and traders would evoke their cooperation rather than their opposition, as would be the case if the mill would attempt to shut them out of its purchasing activities, and past attempts at by-passing the traditional rural trading channels have demonstrated the effectiveness of opposition by local produce merchants.

Plate V.6. shows the Changwats (provinces) and Amphur (districts) in the Northeast encompassed by a circle with a 200 km. straight line radius around Mill Site II, with the Changwat or Amphur capitals with kenaf baling plants underlined. Table V.12. lists those Changwat and Amphur capitals in which baling plants are located and identifies the plants by their JBOT numbers as they are listed in Annex II.

Once more as for whole and chopped whole stalk procurement, it is anticipated that the mill at Site II would, in practice, probably enter into ribbon supply arrangements with a limited number of reputable balers in strategic locations who need not necessarily be restricted to the eight adjacent provinces, where the more distantly located balers would absorb the additional transportation costs so that, in effect, the 270 km. economic road distance limitation would not apply and the entire Northeast would become a potential ribbon supply area; there would then be no problem in securing the entire ribbon raw material requirements in the Northeast, without having to go across



Table V.12.

Baling Plant Locations, Northeast Thailand, Within
Economic Ribbon Transportation Distance from Mill Site II

<u>Changwat/Amphur</u>	<u>Baling Plant JBOT Number</u>
<u>Srisaket</u>	
Muang	- 31, 74, 90, 159, 170, 172, 183
Kanthararom	- 39, 107
Uthamphon Phisai	- 96, 103, 146, 204
<u>Surin</u>	
Muang	- 73, 111, 143, 158, 164, 190
Chom Phra	- 149
Samrong Thap	- 105, 128
Sikhoraphum	- 141, 194
<u>Buriram</u>	
Muang	- 8, 129, 184, 185, 197, 191, 203
Lam Plai Mat	- 131, 193
Phutthaijong	- 202
<u>Roi-Et</u>	
Muang	- 50, 182, 217
Selaphum	- 207
<u>Maharakham</u>	
Muang	- 100
<u>Kalasin</u>	
Muang	- 163
<u>Nakhon Phanom</u>	
Mukdahan	- 60
That Phanom	- 150
<u>Ubon Ratchathani</u>	
Muang	- 3, 11, 43, 45, 54, 55, 88, 93, 114, 120, 133, 157, 166, 167
Warinchamrab	- 20, 29, 36, 39, 71, 116, 161
Yasothon	- 106

the border into Laos or Cambodia, if this should be desired. Also, with more than 200 competing potential suppliers at hand, the mill would be able to select those offering the most advantageous conditions.

Supplementing the above raw material supply arrangements and, hopefully, increasing their contribution progressively, would be kenaf ribbon purchasing agreements with cooperatives and other farmers' organizations, prominently amongst them those operating in the Resettlement Areas of the Department of Public Welfare of the Thai Ministry of the Interior which are located in the southern part of the Northeast. Preliminary discussions with Department executives indicate that, ultimately, up to 100,000 rai (16,000 ha.) might be planted to kenaf by these cooperatives specifically for the pulp mill at Site II within easy reach of which they are located. On the assumption that such production would be exclusively for the pulp mill and that 50 percent of the area could be planted to the higher yielding H. cannabinus variety (see Section 5.3.2. above), these cooperatives could contribute some 54,000 FDMT of bast ribbon annually to the mill's requirements, thus reducing "outside" purchasing requirements to some 106,000 FDMT. Obviously, similar arrangements could also be entered into with other cooperatives, both in Northeast Thailand and in Laos and Cambodia. In each instance, their involvement in large scale raw material supplies to the pulp mill should steadily increase as a result of the technical and input assistance to be furnished to them by the mill.

5.7. Kenaf Ribbon Transport

From the ribbon collection centers - mill operated depots, kenaf balers' or traders' premises, and/or cooperative storage facilities - the ribbon would be transported to the mill site by truck, except possibly from the Buriram, Surin and Sisaket Changwat capitals which are connected to Ubon Ratchathani by railroad.

As indicated in Section 4.3. of this Chapter V, the capacity of the bodies of both the standard 6-ton and 10-ton trucks is 30 cu.m. In Section 5.5. above, it was demonstrated that kenaf ribbon compressed in a Thai kenaf baling press would have a bulk density of approximately 1.74 cu.m./metric ton. Hence, a 10-ton truck could, in theory, load some 17 tons of kenaf ribbon bales and will, in practice, probably carry 12 to 14 tons. By contrast, it could load only a little more than 4 tons, if the ribbon is only field baled. As in the case of baled chopped whole stalks, the ribbon bales would probably most frequently be loaded and unloaded by hand, as is the practice with similar size and weight retted fiber bales.

6. Kenaf Raw Material Availability Projection

One of the decisive considerations affecting the techno-economic feasibility of the establishment of a kenaf based pulp and paper industry in the Lower Mekong Basin is the assurance of a reliable kenaf raw material supply. This section will discuss the various factors influencing the farmers' decision in the Mekong watershed area in each of the four riparian countries to grow kenaf and will attempt to project the reliability of kenaf raw material availability to the industry over the long term.

The actual and potential kenaf production areas in the riparian countries are discussed in detail in Chapter IV of this Study and particular reference is made to Plate IV.3. in that chapter which outlines these areas in each of the four countries.

Since Northeast Thailand is the only traditional large scale kenaf producing area in the Basin and since it is also the only area accessible to the project team at the time of the preparation of this Study, it will again be used as sample area for purposes of kenaf raw material availability discussion.

6.1. Northeast Thailand

6.1.1. The Influence of Farm Prices on Kenaf Output

As is to be anticipated, the area of land which the Northeast farmer devotes to kenaf planting depends to a great extent on the price he received for his fiber during the previous season; this, in turn, depended on both the previous year's local crop size as well as on the size of that year's jute crop in India and Bangladesh which, due to their preponderant position in the jute trade, greatly influence the world market prices of natural packaging material fibers. Thus, a good price in one season will lead to a large kenaf crop in the following season which, if coincidental with a large jute crop in India and Bangladesh, will result in lower prices and, thus, a smaller crop the next following year, a procedure which perpetuates annual crop size and price fluctuations.

Table II.11. and Figs. II.1. and II.2. clearly show these wide annual fluctuations. The peak output of 622,000 tons of retted fiber in 1966, produced on 3.34 million rai (534,000 ha.), was the result of three consecutive years of rising farm prices following short crops in India and Bangladesh and the then still rapidly rising world demand. When the large 1966/1967 Thai kenaf crop coincided with large jute crops in India and Bangladesh, farm level prices in the Northeast collapsed in early 1967 leading to the very low 1968 output of 184,000 tons grown on 1.07 million rai (171,000 ha.), a reduction of some 70 percent. (Regrettably, Thai Ministry of Agriculture statistics are kept on a calendar year rather than on a seasonal - July to June - basis which would have better highlighted this output reduction/price relationship).

A similar fluctuation cycle occurred more recently and is shown in Fig. V.5. The steadily increasing farm prices, starting in 1970/1971 - largely due to the Indo-Pakistani war in what then became Bangladesh and which resulted in drastic jute shortages during a three-year period - led to increasing kenaf planting areas and outputs until, in 1973/1974, the large Thai kenaf output coincided with large jute crops - and disponibilities - in India and Bangladesh and the farm price in the Northeast collapsed. The result was a 25 percent reduction in planting area in 1974/1975 which, combined with a very serious drought, reduced the kenaf output by around 50 percent.

KENAF FARM PRICE / PLANTING AREA RELATIONSHIP NORTHEAST THAILAND, 1969/1970 TO 1974/1975

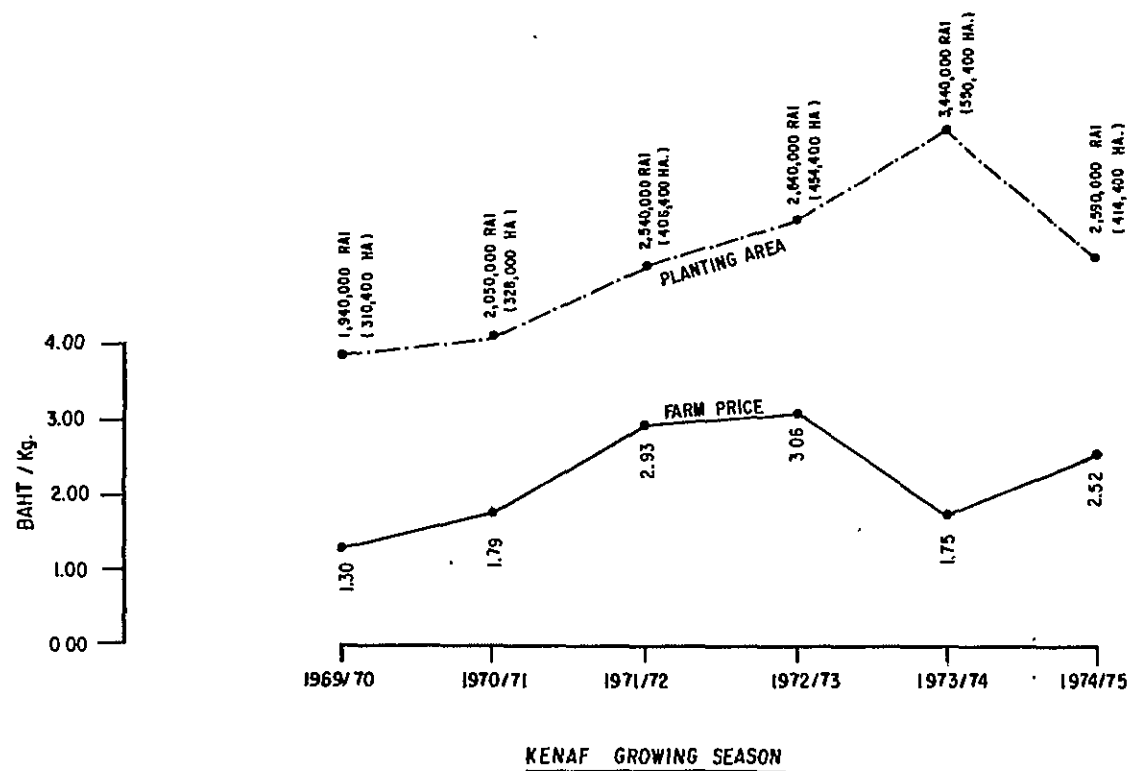


Fig. V.5.

Fig. II.1. also shows that, over the last decade, the kenaf planting area in the Northeast averaged 2.4 million rai (384,000 ha.) per year. An adequate price incentive or, preferably, a farm price above, say ฿2.50/kg. (\$0.125/kg.) and holding at that level over a period of two or more years induced the farmers to increase plantings to some 3.34 to 3.44 million rai (534,000 to 550,000 ha.) or by about 1 million rai (160,000 ha.) or 40 percent.

One of the principal contributions of a kenaf based pulp industry would exactly be its positive influence on both farm level prices and the substantial reduction in year-to-year demand and, therefore, price fluctuations as a result of the guaranteed market and prices the industry can offer to the farmers. This guarantee of a substantial market by the pulp industry would coincide with an even larger assured kenaf demand by the Thai bag and hessian mills (Table II.15.) as well as with mill association established minimum retted fiber prices. It must be anticipated that the combination of these three factors would lead to an increase in the kenaf planting area in the Northeast.

Reasonable annual Northeast Thailand kenaf demand projections, and the corresponding planting area requirements, should then be as shown in Table V.13. The total Northeast wide planting area requirements of 2,375,000 rai (380,000 ha.) and 2,750,000 rai (440,000 ha.) estimated in that table on the assumption of the establishment of a whole stalk kenaf or kenaf bast ribbon pulp mill respectively are equal to and 350,000 rai (56,000 ha.) higher than the actual average annual kenaf planting area in the Northeast over the 1964 to 1974 period (see Table II.13.) but some 1,000,000 rai (160,000 ha.) and 630,000 rai (100,000 ha.) lower than the maximum planting area in 1973. It appears reasonable to assume that, with the proper price incentive and in view of the offer of a guaranteed market by the pulp industry, the required overall kenaf areas will indeed be planted by the Northeast farmers, certainly for either one of the two pulp mills and probably even for both mills, if their establishment should be decided upon.

It is pointed out that the foregoing total planting area requirements refer to H. sabdariffa production only and that they will be reduced in proportion to the substitution of this South Asian kenaf variety by Western Hemisphere kenaf (H. cannabinus) (see Section 5.3.2. above).

Projected Kenaf Demand, Northeast Thailand

Thai Bag Mills	230,000 Tons Fiber ⁽¹⁾	1,250,000 Rai (200,000 Ha.) ⁽²⁾
Retted Fiber Exports	175,000 Tons Fiber ⁽³⁾	950,000 Rai (152,000 Ha.) ⁽²⁾
Northeast Pulp Mill:		
(i) Whole Stalk Kenaf Mill	206,000 Tons Fiber ⁽⁴⁾	172,000 Rai (27,500 Ha.) ⁽⁴⁾
(ii) Kenaf Bast Ribbon Mill	160,000 Tons Ribbon ⁽⁵⁾	555,500 Rai (89,000 Ha.) ⁽⁵⁾
<hr/>		
Total Planting Area Required: (i)		<u>2,372,000 Rai (379,500 Ha.)</u>
(ii)		<u>2,755,500 Rai (441,000 Ha.)</u>

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- Notes: (1) See Table II.15. and Fig. II.5.
(2) At 184 Kg./Rai (1,150 Kg./Ha.) retted fiber yield.
(3) See Chapter II, Section 5.4.
(4) See Table I.21.
(5) See Table I.22.

6.1.2. Kenaf vs. Other Upland Crops

Until recently, kenaf has been the only major upland crop in the Northeast, although by no means the only upland crop grown, as shown in Table V.14. which lists the general upland crop production, exclusive of kenaf and tapioca, in the sixteen Changwats of the Northeast. The crop planting area data listed apply to the 1971 to 1973 period, the most recent years for which reasonably complete statistics are available.

Table V.14. shows an overall general upland crop planting area of some 2,000,000 rai (320,000 ha.) in 1971, 2,400,000 rai (385,000 ha.) in 1972, and 2,700,000 rai (432,000 ha.) in 1973 in the Northeast, substantially more than is generally estimated. It also seems reasonable to assume that such upland crop production has continued to increase at the same approximate rate of 10 percent annually since 1973, particularly in view of the official encouragement given to soyabean and castorbean production, which would bring it up to some 3,250,000 rai (520,000 ha.) in 1975. However, since the 1973 plantings, for example, were obviously in addition to the maximum kenaf plantings of 3.44 million rai (550,000 ha.) per year listed in Table II.13. for 1973, even a further substantial expansion of such general upland crop production should not have a negative effect on the area planted to kenaf, always provided the incentive to grow kenaf exists.

The more serious potential competitor to kenaf for the available upland in the Northeast is tapioca and it has indeed made considerable inroads into the kenaf production areas, particularly in the southern Changwats of the region (Table V.15.). The attraction of tapioca production to the farmer is that it is an easy crop to grow and that it is well adapted to the poor soils such as prevail in the Northeast and is drought resistant. On good quality new land, a yield of 3 to 4 tons/rai (19 to 25 tons/ha.) can be expected initially; on the poorer soils, it averages 2 to 2½ tons/rai (12½ to 15½ tons/ha.). However, yields decrease rapidly due to the highly soil exhaustive properties of the crop and the lack of fertilizer application and they level off at an average of 1 to 2 tons/rai (6 to 12 tons/ha.). Although it proved impossible to secure statistics as to tapioca yields per rai on the upland soils in the Northeast - most of which have been planted to kenaf for many years - some data seem to indicate that they do not average more than 1½ tons/rai (9.375 tons/ha.).

The export market for Thai tapioca products has been increasing rapidly during recent years. Prior to 1973, farm prices averaged about ฿0.20/kg. (\$0.01/kg.); by late 1974, they had risen to ฿0.55/kg.

Table V.14.

General Upland Crop Production, by Changwat
Northeast Thailand, 1971 to 1973

Crop	Year	Buriram	Chaiyaphum	Kalasin	Khonkaen	Loei	Mahasarakham	Nakhon Phanom	Nakhonrachasima	Nongkhai	Roi-Et	Sakonnakorn	Sisaket	Surin	Udon Thani	Ubolrajthani	Yasothon	Total	
																		Rai	Re.
Corn	1971	27,267	29,235	45	5,404	207,596	140	627	740,007	4,151	1,839	608	92,804	-	5,667	16,857	-	1,132,248	181,160
	1972	23,970	34,280	1,193	11,187	208,050	2,577	594	841,259	2,029	3,301	556	95,450	1,907	24,929	17,784	74	1,269,150	203,064
	1973	28,906	66,873	1,994	7,980	338,933	2,471	-	933,471	2,066	2,085	6,078	171,954	168	37,900	22,230	-	1,623,109	259,697
Peanuts	1971	16,908	14,916	4,778	4,442	9,017	2,765	1,385	78,034	3,856	11,346	2,647	8,293	4,695	6,530	4,486	-	174,098	27,856
	1972	30,058	14,541	3,050	4,338	6,267	7,883	1,823	117,955	2,204	9,307	4,019	8,444	7,953	6,442	5,237	804	230,323	35,852
	1973	55,077	21,098	5,499	3,681	14,881	7,075	-	94,612	3,117	8,239	7,915	17,891	15,377	5,105	9,346	1,713	272,626	43,620
Mung Beans	1971	794	1,274	255	647	2,789	-	437	25,816	2,599	1,092	204	2,354	578	995	1,854	-	41,638	6,662
	1972	75	6,220	422	593	8,054	563	446	11,960	615	957	411	2,270	501	1,085	562	-	34,754	5,561
	1973	291	1,131	1,053	1,746	4,732	340	-	13,721	80	591	3,065	127	803	2,062	765	380	38,827	4,932
Soya Beans	1971	-	337	479	46	3,585	29	134	3,305	-	850	348	166	430	240	1,357	-	11,305	1,869
	1972	271	497	382	323	5,991	54	249	5,446	1,196	191	239	544	470	1,173	2,251	333	19,612	3,138
	1973	259	453	154	913	7,000	106	-	7,225	175	-	918	352	60	1,286	2,401	38	21,346	3,415
Sorghum	1971	-	120	107	292	175	-	321	4,338	34	82	175	103	140	1,216	-	-	7,103	1,137
	1972	64	160	33	-	-	31	279	4,886	10	-	136	12	92	-	46	-	5,751	920
	1973	276	968	-	-	-	-	-	16,670	195	6	6	12	5	64	45	-	18,247	2,920
Sesame	1971	16,732	230	732	891	9,682	113	591	771	505	1,563	569	123	285	1,368	1,037	-	35,172	5,628
	1972	32,991	175	789	538	20,794	241	562	585	1,232	918	629	2,440	290	3,477	567	172	66,400	10,624
	1973	8,083	84	677	856	25,424	363	-	770	1,111	409	1,479	662	327	1,821	577	327	42,970	6,875
Cotton	1971	2,854	6,616	6,960	4,720	102,980	127	4,110	24,260	7,873	3,707	8,529	241	-	26,322	218	-	199,717	31,955
	1972	808	11,505	2,424	31,372	143,132	938	3,431	38,356	6,390	4,584	4,578	1,364	-	12,443	857	761	265,143	42,423
	1973	1,475	1,679	2,225	1,751	28,962	245	-	6,411	957	953	7,177	891	-	3,029	1,016	1,078	57,359	9,177
Castor Beans	1971	-	176	60	2,035	25	-	75	27,351	5	556	192	574	216	1,150	150	-	32,565	5,210
	1972	624	135	20	166	-	-	190	31,932	19	605	125	590	162	330	172	-	35,070	5,611
	1973	2,170	3,039	400	365	3,773	-	-	33,449	33	131	311	1,113	161	878	313	17	46,153	7,384
Sugar Cane	1971	27,586	391	235	1,909	3,670	-	4,360	10,084	354	794	4,074	-	1,372	116,720	-	-	171,549	27,448
	1972	29,975	1,245	611	1,582	2,600	541	4,760	7,342	765	564	7,820	-	-	105,465	847	137	164,254	26,281
	1973	33,389	1,756	1,197	2,504	6,215	151	-	7,000	745	313	9,347	60	2,283	133,423	752	260	199,575	31,932
Jute	1971	600	239	228	24	-	-	151	-	3,756	-	250	9	14	1,918	-	-	7,229	1,157
	1972	1,823	642	1,085	3,155	2,410	779	602	1,131	26,227	2,225	977	55	26	11,300	2,790	985	56,213	8,994
	1973	5,806	50	13,159	2,029	10,851	59	-	623	46,003	1,211	8,691	84	16	14,885	1,517	71	105,055	16,809
Sub-Total	1971	92,107	53,525	13,879	20,410	339,519	3,174	12,191	913,966	23,173	21,829	17,576	104,667	7,730	162,326	25,959	-	1,812,031	289,925
	1972	120,659	69,400	10,030	53,254	397,298	13,607	14,936	1,060,856	40,897	22,652	19,490	111,169	11,401	166,644	31,113	3,266	2,146,672	343,468
	1973	135,712	97,131	26,358	23,831	440,771	10,810	-	1,113,952	54,492	13,938	45,127	192,646	19,200	200,453	38,962	3,884	2,417,267	386,763
Vegetables	1971	7,244	8,878	6,649	25,890	19,548	12,779	8,845	32,925	15,225	10,703	3,677	9,791	7,709	17,721	11,253	-	199,037	31,646
	1972	10,363	6,178	8,894	16,853	31,495	21,726	14,356	35,206	12,772	16,155	2,230	21,448	8,413	13,694	33,268	11,461	264,520	42,323
	1973	20,202	6,418	8,668	16,971	55,045	26,564	-	42,820	10,578	9,758	8,450	10,658	7,710	33,331	12,774	8,018	277,165	44,346
Total	1971	99,351	62,603	20,528	46,300	359,067	15,953	21,036	946,891	38,398	32,532	21,453	114,458	15,439	180,047	37,212	-	2,011,068	321,771
	1972	131,022	75,578	18,924	70,109	428,793	35,333	29,292	1,096,062	53,669	38,807	21,720	132,617	19,820	180,338	64,381	14,727	2,411,192	385,791
	1973	155,914	103,549	35,026	40,802	495,816	37,374	-	1,156,772	65,070	22,696	53,577	203,504	26,910	233,784	51,736	11,902	2,694,432	431,109

Source: Department of Agricultural Extension, Ministry of Agriculture

Tapioca Production, Northeast Thailand
1971 to 1974

Table V.15.

		Unit = Rai			
Changwat		1971	1972	1973	1974
Buriram		2,133	33,452	67,542	428,073
Chaiyaphoom		2,540	9,412	37,305	54,678
Kalasin		10,574	51,684	71,341	92,743*
Khon Kaen		2,272	13,346	82,834	80,742
Loei		292	2,704	13,195	17,154*
Maharakam		564	4,567	14,839	20,752
Nakorn Phanom		3,780	24,519	31,875*	41,438*
Nakorn Ratchasima		169,390	239,575	493,512	641,566*
Nong Kai		1,140	12,631	31,125	40,463*
Roi-Et		1,606	3,276	9,499	24,785
Sakorn Nakorn		1,007	4,803	15,932	20,712*
Sisaket		1,036	1,670	2,050	2,665*
Surin		90	119	16,302	33,235
Udorn Thani		13,205	22,086	74,113	90,571
Ubon Ratchathani		1,343	3,640	6,543	10,715
Yasothon	(incl. in Ubon)		389	8,434	7,292
TOTAL:	Rai	210,972	427,873	944,566	1,607,584
	Ha.	33,756	68,460	151,131	257,213

Note: *Data not available; increase estimated at 30% over previous year.

Source: Department of Agricultural Extension

and they maintained that level through most of 1975. Discussions with Government officials and prominent tapioca exporters indicated that, over the long term, they could be expected to average some $\text{฿}0.40/\text{kg}$. At that price level and at an average yield of $1\frac{1}{2}$ tons/rai, the gross revenue to the tapioca grower would amount to $\text{฿}600/\text{rai}$ ($\text{\$}187.50/\text{ha.}$).

It is official Thai Government policy to discourage tapioca production due to fear of widespread soil exhaustion, and this is supported by such measures as withholding farm loans, discouraging the establishment of new tapioca processing plants, etc. Nevertheless, it must be anticipated that the farmers will continue to grow tapioca as long as the price incentive and the assured market exist, and it would be wishful thinking to expect a reduction in tapioca production in the Northeast. However, it seems reasonable to assume that, given a competitive incentive for kenaf production, the latter's output will be maintained at a level at which a firm demand exists.

As far as labor requirements are concerned, tapioca is considerably less labor intensive than retted kenaf fiber production; however, it requires slightly more labor than whole kenaf stalk production for pulp manufacture and probably about the same amount of labor as bast ribbon production.

The above estimated gross farm revenue for tapioca, under Northeast Thailand conditions, of $\text{฿}600/\text{rai}$ ($\text{\$}187.50/\text{ha.}$) is equivalent to that for retted kenaf - or whole stalks and/or bast ribbon sold to the pulp mill - at the $\text{฿}3.25/\text{kg}$. "Mixed Grade" price level and kenaf stalks and/or ribbon for paper pulp remain, therefore, competitive from the revenue point of view (see Tables VIII.4. and VIII.5.).

With regard to the availability of upland crop areas, it is pointed out that the expansion of both tapioca and general upland crop production did not reduce kenaf output in the Northeast in the past as demonstrated by the fact that between, say, 1970 and 1973 the area under all three crop categories - general upland crops, tapioca and kenaf - increased simultaneously and that only an unfavorable crop price level led to a reduction in kenaf output in 1974.

It is, therefore, concluded that for kenaf for paper pulp production (i) the availability of upland crop areas in Northeast Thailand is not a limiting factor of the stalk or ribbon supply potential; that (ii) an adequate price incentive will assure an adequate supply; and that (iii) the farm price for field dry kenaf stalks and/or ribbon to be offered by the kenaf pulp mills constitutes such an adequate price incentive.

6.2. Laos

In view of the absence of Government authorization to visit the potential kenaf production areas, any assessment by the Consultants of likely future raw material availability to a kenaf based pulp and paper industry "within economic transportation distance" from the potential mill sites can only be very tentative at best at this time and detailed on-the-spot investigations - along the lines of those described for Northeast Thailand in the preceding Sub-Section 6.1. - will be required before reasonably reliable projections can be prepared. Obviously, this applies not only to Laos but also to Cambodia and Viet-Nam.

As discussed in Chapter II, Section 3., of this Study, kenaf has never been produced commercially in Laos since a local market for kenaf fiber, namely a bag and hessian mill, did not exist in the country and the limited kenaf packaging material requirements could always be covered easily from neighboring Northeast Thailand. Because of the small size of the pulp and paper market in Laos and the unlikelyhood that a local mill could successfully compete on the export market in view of its lack of access to an outlet to the sea within reasonable distance, it is also improbable that such a mill will be established in Laos in the reasonably near future. Hence, a kenaf for paper pulp production program in Laos would have to supply raw material to mills in neighboring Thailand and Cambodia.

In Chapter IV, Section 3., it was demonstrated that, of the suitable kenaf production areas in Laos, parts of the Provinces of Savannakhet, Sedone and Sithandone and all of Champassac Province lie within economic whole stalk transportation distance from the projected Mill Site II near Ubon Ratchathani in Northeast Thailand, and all of Sithandone Province is included in the whole stalk supply area of Mill Site III at Stung Treng in Cambodia. Furthermore, the Vientiane Plain can economically supply kenaf bast ribbon to Mill Site I at Nam Phong in Northeast Thailand and practically all of the other potential Lao production areas can do so as far as Mill Site II and/or Mill Site III is concerned. Hence, there seems no doubt that an ample potential market exists for Laos produced kenaf, if and when one or more pulp mills should be established in Northeast Thailand or Northeastern Cambodia.

As to whether the Lao farmers would indeed produce kenaf for any future pulp industry, this would largely depend on the revenue they could realize from such production as compared to that from other cash crops they could raise on their land and for which a ready market

existed. At this time, the Consultants can only assume that the competitive position between kenaf and other upland crops would be similar to that prevailing in Northeast Thailand and possibly somewhat more in favor of kenaf since the Northeast farmer is likely to have easier access to markets for his upland crops than his Lao counterpart. Subject to the various reservations expressed above, it would appear that a pulp mill at Site II should have no difficulty in securing the kenaf bast ribbon from a 240,000 rai (38,400 ha.) H. sabdariffa and/or a 108,000 rai (17,300 ha.) H. cannabinus planting area in Laos to make up any possible supply deficit from Northeast Thailand sources (Section 5.3. above) and could, most likely, secure several times that amount of ribbon.

6.3. Cambodia

The same limitations resulting from the present inaccessibility of the potential production areas to the project team as in the case of Laos also apply to the assessment of kenaf for paper pulp raw material availability in Cambodia. Nevertheless, the positive results of past kenaf promotion programs seem to indicate that adequate supplies would become readily available once an assured market exists.

Chapter II, Section 2., points out that the farmers in seven provinces in central and western Cambodia responded well to the introduction of kenaf between 1967 and 1971 at which time the only market for the crop was the gunny bag factory at Battambang; also that two kenaf crops per year can be grown under local climatic conditions. In Chapter IV, Section 4., it is demonstrated that, on the basis of soil conditions, kenaf can be grown almost anywhere in the country. Plate IV.6. in that section further shows that the northern, central and eastern sections of Cambodia lie "within economic (raw material) transportation distance" of Mill Site II and/or Mill Site III.

From the above it would appear that the potentials for large scale kenaf for paper pulp production in Cambodia do indeed look favorable, always provided the pulp mills are in a position to offer an adequate crop price inducement which, using neighboring Thailand as yardstick, seems likely. In particular, a pulp mill established at Site III should experience no difficulty in securing adequate supplies of both whole stalk or bast ribbon raw material supplies, i.e. the crop from between 10,000 ha. and 28,000 ha. in the case of whole stalks and from 34,000 to 89,000 ha. in the case of bast ribbon (see Tables I.16. and I.17.).

6.4. Viet-Nam

The discussion of potential kenaf for paper pulp raw material supplies from Viet-Nam in this Study is circumscribed by the fact that, as pointed out in Chapter IV, Section 5., only the Provinces of Kontum, Pleiku and Darlac are (i) suitable potential kenaf production areas, and (ii) located within the Mekong watershed, since the Delta soils, generally speaking, do not provide adequate drainage and, in any case, are too valuable for food crop production to be used for kenaf.

Extensive areas do indeed exist in Kontum, Pleiku and Darlac which would be suitable for kenaf production (Chapter IV, Section 5.) and the crop has been introduced into that area in the past (Chapter II, Section 4.1.). However, the Consultants have no personal experience of agronomic conditions in the Central Highlands of Viet-Nam and are, therefore, quite unable to make any reasonable projection, particularly since they have been unable, in the absence of official authorization to visit the area, to assemble the required supporting information.

As related in Chapter II, Section 4., kenaf (and jute) has been widely introduced in Viet-Nam in the past and appears to have been grown successfully in almost all upland areas of the country, and it must be assumed that any future kenaf for paper pulp development program in Viet-Nam would include several other provinces in addition to the Mekong Basin Provinces of Kontum, Pleiku and Darlac. Again, a kenaf pulp mill in Viet-Nam should have no problem in assuring itself of the required raw material supplies.

7. Pulp Mill Demonstration Farm

Reference has already been made in Chapter III, Section 4.3., and elsewhere in this Study to the desirability of the establishment of one or more kenaf farm units by the pulp mill(s) to support the small holders' production efforts through the supply of such inputs as mechanical equipment services, improved seed, and fertilizer and pesticides, possibly on a credit basis, as well as through the provision of demonstration and extension services. Such a pulp mill operated farm would, obviously, have to be organized along commercial plantation lines; it would also have to be located in an area where the soil is suitable for H. cannabinus production which would then permit the growing of the H. sabdariffa species as well. The production of the former will be discussed in detail in this Section 7.

In the following, one such Demonstration Farm is described from both the organizational and operational points of view. Since, at the present Pre-Feasibility Study stage, it is impossible to establish desirable individual Demonstration Farm areas, a 240 ha. (600 acres; 1,500 rai) basic farm unit is discussed, multiples of which can then be set up to meet larger production and/or small holder supporting service requirements. It is assumed that, since the farm will have to employ paid labor - as opposed to the small holders using uncostered family labor - its operations will be extensively mechanized.

7.1. Cultural Practices

7.1.1. Land Clearing

The amount of land clearing required, and its cost, will depend on the farm location. It should be kept in mind that, for subsequent mechanization of cultural operations, the land must be completely cleared and stumped. Since it would be uneconomical for the farm to purchase its own caterpillar-type tractors for the clearing of the limited areas involved, these services will be contracted out.

It being assumed that the Demonstration Farm will be established on reasonably fertile soils permitting the economic production of the H. cannabinus species of kenaf, the project area can reasonably be expected to be covered by moderately dense forest. It is also assumed, for estimation purposes, that the farm will be located in the general area of Mill Site II, near Ubon Ratchathani in Northeast Thailand; average land clearing charges in that area are presently approximately US\$160 per hectare.

7.1.2. Land Preparation

Land preparation on the Demonstration Farm would be completely mechanized. This is necessary to assure a fine tilth on the heavier soils so that the kenaf seed is evenly spaced during planting.

The Demonstration Farm could, in principle, arrange for land preparation services with a local contractor. However, in order to assure that all mechanized operations are indeed executed on time and when required for optimum operation, it is assumed herein that the Farm will acquire its own tractors and equipment.

Thorough mechanized land preparation consists of disc-plowing followed by harrowing and cross-harrowing. These operations can be initiated shortly after the end of the rainy season, say about the second half of November in Northeast Thailand, and should be completed prior to the start of the rains, or about the end of April.

7.2. Seed Planting and Fertilization

The start of seed planting is scheduled for the first week of May, at the beginning of the rainy season, and would continue until the first week of August. In the case of whole stalk and chopped stalk kenaf raw material production, this staggered planting schedule permits the more efficient use of the available mechanical equipment; for bast ribbon production, where the ribboning operation has to be carried out on reasonably fresh stalks for maximum yields, it additionally allows an extension of the harvesting season and, thus, a more extended use of the ribboning machines. It is made possible through the use of the several commercially available H. cannabinus seed varieties with differing photo-period responses, particularly C-2032 (early to medium maturing) and G-4, G-45 and G-51 (late maturing).

Seed planting would be done by tractor-drawn seed drill. The average seeding rate for H. cannabinus is 25 kg./ha. (22 lbs./acre; 4 kg./rai) and the standard 21-row small grain drill to be utilized will permit a planting distance of 17.5 cm. (7 in.) between rows (see Section 2.3.2. of this Chapter V).

In view of the uncertainty as to the exact location of the subject Demonstration Farm and the soil quality at that location, recommendations as to types and quantities of fertilizer to be applied can only be tentative and based on experience elsewhere. At this time, and for purposes of cost estimation only, the application of 135 kg. of urea and 135 kg. of, say, 15:15:15 composite fertilizer per hectare is assumed. The fertilizer would be applied at the time of seed planting by using a seed drill with a fertilizer box.

As discussed in Section 2.5.2. of this Chapter V, the shading effect of the palmate leaves and the rapid seedling development of the H. cannabinus species of kenaf has the effect of suppressing weed growth so that no weeding operation is required, as is the case with H. sabdariffa. However, in order to achieve this end, it is essential that the weeds are not allowed any headstart on the kenaf and a third harrowing operation must be carried out immediately prior to seed planting so as to eliminate any weeds which might have emerged subsequent to the second harrowing.

7.3. Harvesting and Processing

7.3.1. Whole Stalk Production

Harvesting for whole stalk kenaf raw material production for the pulp mill should be scheduled to start after the standing crop has begun to dry out after the end of the rainy season and as a result of stalk age. For the Lower Mekong Basin, this would mean any time after about the middle of December. In most kenaf producing countries, the stalks are cut by hand and the normal task is 25 man-days/ha. (10 man-days/acre; 4 man-days/rai). However, in line with the policy of maximum mechanization of the Demonstration Farm operations, stalk harvesting on that farm will also be mechanized.

The stalks could be harvested by means of a side-mounted cutter-bar attachment to a tractor. However, due to their inter-twining leaf crowns, the stalks would then not fall evenly and they would have to be aligned before field bundling which, since such bundling would have to be done by hand in any case, would present no great problem. Nevertheless, a more efficient and labor saving method is to cut the stalks by means of a special high-crop harvesting attachment which is front-mounted on a tractor and has proved quite satisfactory in past kenaf operations although it still requires some modifications. The attachment cuts the stalks at ground level, bundles and loosely ties them with one central tie, and throws out the bundles at right angles to the direction of travel of the tractor. One unit can easily harvest 160 to 180 ha. (400 to 450 acres; 1,000 to 1,125 rai) during a 3½ to 4 months harvesting period, as determined by the requirement to complete the operation well ahead of the scheduled start of next season's seed planting.

The loose stalks or loosely tied stalk bundles would then be assembled, topped and field bundled as already described in Section 3.4.4. of this Chapter V.

7.3.2. Chopped Stalk Production

As for whole stalks, chopped stalk harvesting should start not earlier than mid-December so as to allow the standing crop to first lose much of its moisture content. In principle, the stalks could again be cut and then chopped by hand, but the operation would be mechanized on the Demonstration Farm.

As already discussed in Section 2.8.2.2. of this Chapter V, extensive mechanized chopped stalk harvesting tests have been carried out in the U.S.A. in the past and it appears that, pending the development of specific kenaf stalk harvesting/chopping equipment, the standard forage harvesters proved to be adequate and, more particularly, the pull-type forage harvesters. It is, therefore, proposed to use this latter type of equipment on the Demonstration Farm. The forage harvester will chop up the stalks into suitable lengths and blow the chips into a trailer pulled behind the unit.

Again, the harvesting operation should be completed well before the scheduled starting date of next season's seed planting at the beginning of May.

7.3.3. Bast Ribbon Production

Whereas a substantial degree of flexibility in the timing of whole stalk or chopped stalk harvesting is permissible, this is not the case for bast ribbon production. For maximum bast ribbon yields, the bast must be stripped from the central core at between 120 and 150 days of stalk age for H. cannabinus - and hence the importance of staggered planting and the use of seed varieties with different photo-sensitivities. In order to comply with this condition and since seed planting would take place between the first week of May and the first week of August, stalk harvesting and bast ribboning must be carried out between the beginning of September and the end of December.

As in the case of whole stalk production, the crop would be harvested by means of tractor front-mounted high-crop harvesters where, in this instance, the progress of harvesting would be adjusted to the available ribboning capacity which, in turn, would be such as to permit completion of the combined operation not later than the end of December. It should be noted, that the crop should be ribbioned within 48 to 72 hours of its being harvested. Whereas the bast ribbon could be stripped off the central stalk by hand in small holder operations, this task would again be done by mechanical equipment under commercial conditions as are assumed to prevail on the Demonstration Farm.

The subsequent kenaf ribbon drying and field baling operations have already been described in Section 5.5. of this Chapter V, where the dry ribbon would be field baled in open-topped wooden boxes as described in that section. Ribbon field drying and baling would not be mechanized.

7.4. Operating Schedules and Equipment Requirements

In order to establish the mechanical equipment operating schedule and the related equipment requirements, the Demonstration Farm has been broken down into 240 ha. (600 acres; 1,500 rai) "units". As will be seen in Table V.16., each such unit will require three tractors to complete the various mechanical operations within the proscribed time periods but, although not shown in Table V.16., each unit will also be furnished with a fourth tractor to be used for general transportation purposes and as a stand-by.

As indicated in Table V.16., the basic tractor operating schedule is assumed to be 45 hours in 5½ working days per week. This is a more than conservative assumption; the Thai Ministry of Agriculture uses a 60-hour week as a basis for tractor operation calculations. Furthermore, it is assumed that wheel-type tractors in the 70 to 80 HP range would be used and the estimates of time per hectare required for plowing, harrowing and seed planting are based on that tractor horsepower range. Again, it will be seen that the estimates are most conservative.

7.4.1. Whole Stalk Production

The determining factor with regard to land preparation scheduling is the start of the planting operation by which time land preparation must, obviously, be completed. At the same time, consideration must be given to the stalk harvest which, in the case of whole stalk production, overlaps with the land preparation period. Table V.16. shows, in detail, how these operations can be scheduled in such a manner that a pool of three tractors can complete them on time for a 240 ha. Demonstration Farm Unit.

As will be seen, Tractor No. 3 starts plowing at the beginning of January, at which time Tractors Nos. 2 and 1 are still engaged in stalk harvesting which they complete at the end of the second and fourth week of March respectively. They then take over the balance of the plowing from Tractor No. 3 which switches over to 1st. harrowing and, from the middle of April onwards, alternates the 1st. and 2nd. harrowing operations assisted, during a three-week period in April, by Tractor No. 2. At the beginning of May, Tractors Nos. 1 and 2 start seed planting and 3rd. harrowing respectively, where the progress of the 3rd. harrowing is slowed down so as to accommodate the progress of the seeding and fertilization operations which it must immediately precede. Seed planting is completed during the first week of August.

The capacity of the tractor front-mounted high-crop harvesting attachment has, at 10 ha. per 45-hour week, been assumed very much on the low side and should, in actual practice, be substantially greater and compare favorable with that of the forage harvester. At the low capacity assumed herein, two high-crop harvester equipped tractors would be required to complete the harvest in time so as to permit, in turn, the timely completion of land preparation. As shown in Table V.16., Tractor No. 1 would then start harvesting during the last but one week in December and would be joined by Tractor No. 2 at the beginning of January; the harvest would be completed between the middle and the end of March.

As Table V.16. demonstrates, tractor and equipment utilization for kenaf whole stalk production for paper pulp is badly balanced with intensive utilization during the first seven months of the year and no utilization during the last five months. This is, of course, due to the necessity of completing seed planting by the beginning of August on the one hand, and the desirability of delaying the start of the stalk harvest until the end of December on the other hand.

7.4.2. Chopped Stalk Production

The seed planting and fertilization and its associated 3rd. harrowing operations obviously being scheduled for the same time frame (beginning of May to first week of August) as for whole stalk production, land preparation is also scheduled in a similar manner although the fact that the forage harvester is assumed to have twice the capacity of the high-crop harvester permits a greater degree of flexibility, since only one tractor will be required for the harvesting operation rather than two as previously.

As shown in Table V.16., Tractors 2 and 3 will start plowing during the third week in January, at which time Tractor No. 1 is still engaged in harvesting. Tractor No. 3 switches over to 1st. harrowing during the third week in March, followed by Tractor No. 1 one week later and by Tractor No. 2 two weeks later. Tractor No. 3 then starts the 2nd. harrowing during the last week in March whilst Tractors Nos. 1 and 2 turn to seed planting and fertilization and 3rd. harrowing at the beginning of May, a task which they complete during the first week of August.

The capacity of the pull-type forage harvester to be used for stalk harvesting/chopping has been estimated on the basis of the results obtained during past tests in the U.S.A. Table V.3. shows an effective capacity for this unit of 7.65 OD (oven dry) tons of stalks per hour or, to be conservative, say of 7.5 FD (field dry) tons of stalks per hour. On the assumption of an average FD stalk yield of 15 tons/ha. for H. cannabinus (Table I.16.), it would then require 2 hours to harvest/chop one hectare; during a 45 hour working week, the forage harvester could then process 22.5 ha. or, to be even more conservative, 20.0 ha. The harvest of the 240 ha. Demonstration Farm Unit kenaf stalk crop would then require 12 weeks as shown in Table V.16., with the harvesting/chopping operation being scheduled to start at the beginning of January and to be completed during the fourth week of March.

The stalk chips blown by the forage harvester into a follow-up trailer are assumed to already have a low enough moisture content to be ready for bulk transport or for baling without additional drying, since they have been harvested long enough after the end of the rainy season and at a stalk age at which even the standing stalks dry out after the flowering and seed bearing stage.

7.4.3. Bast Ribbon Production

Once more, the seed planting and fertilization and its associated 3rd. harrowing operations would be scheduled for the period of beginning of May to first week of August, and land preparation must, therefore, be completed by the end of April. Since bast ribboning would be completed by the end of December, all three tractors could be used for plowing and 1st. and 2nd. harrowing, so that the start of the land preparation operations could be delayed until the beginning of February.

Whereas the bast ribbon would be stripped off the central stalk by hand in small holder operations, this task would also be done by mechanical equipment under commercial conditions as are assumed to prevail on the Demonstration Farm. The available types and capacities of kenaf ribboning machines have already been described in Section 2.8.2.3. of this Chapter V. For purposes of this Study, the average ribboner capacity will be assumed to be 0.5 ha. (1.25 acres; 3.125 rai) per 7½ to 8 hours work shift.

As pointed out in the foregoing Section 7.3.3., the bast must be stripped from the central core at between 120 to 150 days stalk age. Table V.17. then shows that, with a first week of May to first week of August planting period, this condition can be complied with by starting the harvest at the beginning of September and, for the 240 ha. Demonstration Farm Unit, harvesting at the rate of 15 ha. per week. The September 1 to December 22 harvesting/ribboning period shown in Table V.16. comprises 16 weeks at $5\frac{1}{2}$ working days or a total of 88 working days. At the above ribboner capacity of 0.5 ha./day, each machine would be able to process 44 ha. (110 acres; 275 rai) of kenaf crop per season, and a total of 5.45 or, say, 6 ribboners would be required to process the 240 ha. Demonstration Farm Unit crop.

The subsequent kenaf ribbon drying and baling operations have already been described in Section 5.5. of this Chapter V, where the dry ribbon would be field baled in open-topped wooden boxes, as described in that section. Ribbon field drying and baling would not be mechanized.

Table V.17.

Planting and Harvesting Schedule
240 Ha. Demonstration Farm Unit

Planting			Harvesting			
Variety	Date	Ha.	Date	Ha.	Crop Age	
					Ha.	Days
C-2032	May 1	18	Sept. 1	15	15	123
C-2032	May 8	18	Sept. 8	15	3	130
C-2032	May 15	18			12	123
C-2032	May 23	18	Sept. 15	15	6	130
G-45	June 1	18			9	123
G-45	June 8	18	Sept. 23	15	9	130
G-45	June 15	18			6	123
G-45	June 23	18	Oct. 1	15	12	129
G-51	July 1	18			3	122
G-51	July 8	18	Oct. 8	15	15	130
G-51	July 15	18	Oct. 15	15	15	129
G-51	July 23	18	Oct. 23	15	3	137
G-51	Aug. 1	18			12	130
G-51	Aug. 8	6	Nov. 1	15	6	138
					9	131
			Nov. 8	15	9	138
					6	131
			Nov. 15	15	12	137
					3	130
			Nov. 23	15	15	138
			Dec. 1	15	15	138
			Dec. 8	15	3	146
					12	138
			Dec. 15	15	6	145
					9	137
			Dec. 23	15	9	145
					6	137

7.5. Equipment, Facility and Personnel Requirements

The Tractor Operating Schedule (Table V.16.) shows that, for each of the three types of kenaf raw material production for paper pulp - whole stalks, chopped stalks, bast ribbon - three tractors will be required for the 240 ha. Demonstration Farm Unit. An additional fourth tractor should be made available for general transportation duties and as a stand-by unit.

The tractor implement and general transportation equipment requirements will also be the same for all three types of production, namely three disc-plows, three disc-harrows, one 21-row seed drill with fertilizer box, three 3-ton trailers, and one 5-ton truck.

For stalk harvesting and/or processing, whole stalk production will require two high-crop harvesters; for chopped stalk production, the two high-crop harvesters are replaced by one pull-type forage harvester; and for bast ribbon production, two high-crop harvesters and six ribboning machines will be required.

The equipment requirements per 240 ha. Demonstration Farm Unit may then be summarized as shown in Table V.18.

Including an allowance for land occupied by farm roads and buildings, a total of some 250 ha. would be required for each Demonstration Farm Unit. On the assumption that overall administration and maintenance services and raw material storage facilities would be available at the pulp mill, only a storage shed of, say, 10 m. x 20 m. and including simple office facilities would need to be provided for each Unit.

As far as personnel requirements are concerned, each Demonstration Farm Unit would be administered by a Farm Manager assisted by two Field Managers/Supervisors. The only other permanent staff would consist of four tractor drivers and their four helpers; the remainder of the work force would be employed on a temporary basis as and when required for the harvesting and/or bast ribboning operations (see also Chapter VIII, Section 7).

Equipment Requirements
240 Ha. Demonstration Farm Unit

Equipment \ Production	Whole Stalks	Chopped Stalks	Bast Ribbon
Tractor, 75 HP.	4	4	4
Disc-Plow, 3 Discs	3	3	3
Disc-Harrow, 7 Discs	3	3	3
Seed Drill, 21-Row	1	1	1
Trailer, 3 Tons	3	3	3
Truck, 5 Tons	1	1	1
High-Crop Harvester	2	-	2
Forage Harvester	-	1	-
Ribboner	-	-	6



Photo 1 - Plowing with Animal-Drawn Wooden
Plow, Thailand



Photo 2 - Raking with Animal-Drawn Wooden
Rake, Thailand



Photo 3 - Row-Planting with Marking String - Furrow
Opening and Kenaf Seed Dibbling, Thailand



Photo 4 - Animal-Drawn Kenaf Planting Rake,
Thailand

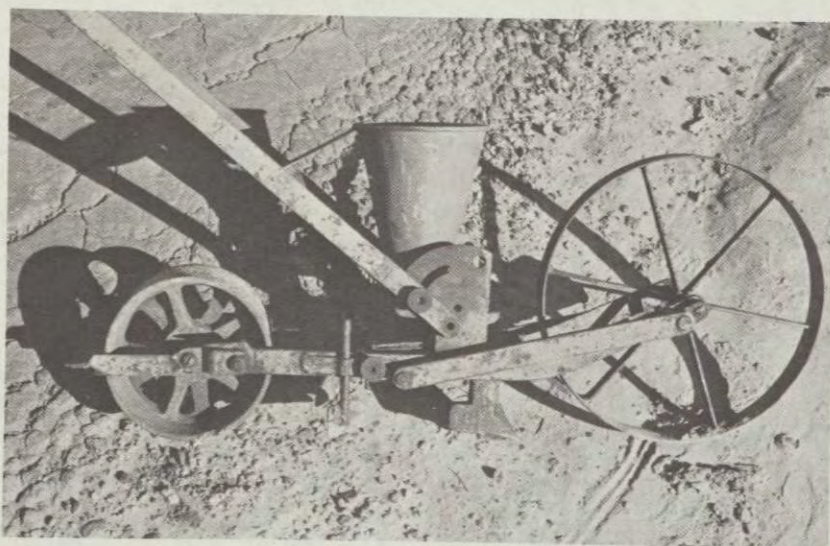


Photo 5 - Hand-Pushed Jute and Kenaf Seed Drill,
Bangladesh



Photo 6 - H. sabdariffa Seedling,
20 Days Old, Thailand



Photo 7 - Line-Sown H. sabdariffa, 60 Days Old,
Thailand



Photo 8 - Line-Sown H. sabdariffa,
150 Days Old, Thailand

ASL



Photo 9 - Thinning of Row-Planted H. sabdariffa,
Thailand



Photo 10 - Thinned Row-Planted
H. sabdariffa, Thailand



Photo 11 - Flowering Stage of H. sabdariffa,
Thailand



Photo 12 - H. sabdariffa Flower and Seed
Capsules, Thailand



Photo 13 - Bushknife Harvesting of H. sabdariffa,
Thailand



Photo 14 - H. sabdariffa Stalks
Shocked after Harvest,
Thailand



Photo 15 - H. sabdariffa Stalks
Shocked for Field Storage,
Thailand



Photo 16 - Bullock Cart Transport of Kenaf
Stalks, Thailand



Photo 17 - Hand Ribboning of Kenaf



Photo 18 - Hand Ribboning of Kenaf with
Stripping Table



Photo 19 - Bullock Cart Transport of Kenaf Bast
Ribbon Bundles



Photo 20 - Tractor Plowing, Kenaf Demonstration
Farm, Zambia



Photo 21 - Tractor Disking, Kenaf Demonstration Farm, Zambia



Photo 22 - Seed Planting with 21-Row Tractor-Drawn Seed Drill with Fertilizer Box, Zambia



Photo 23 - Line-Sown H. cannabinus, 8 Days after Seeding, Zambia



Photo 24 - H. cannabinus, 35 Days Old, Stalk Height = 78 cm., Zambia

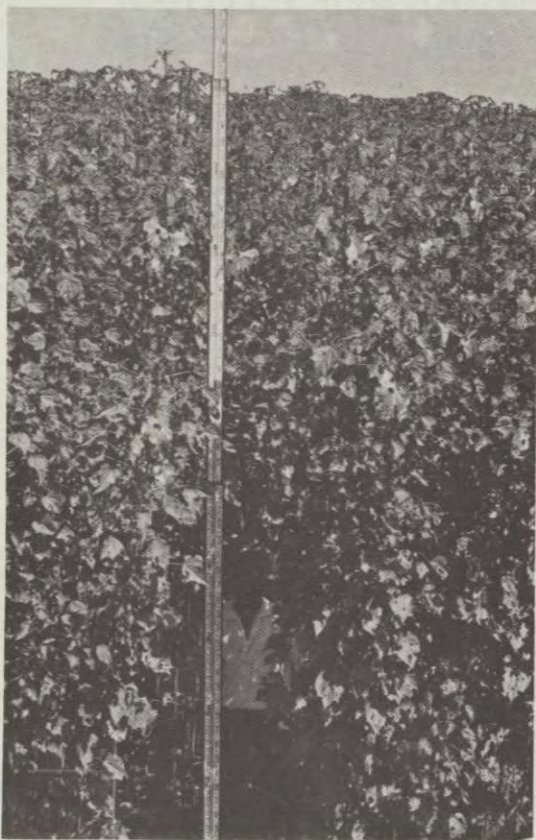


Photo 25 - H. cannabinus, 120 Days
Old, Stalk Height - 3.50 m.,
Zambia



Photo 26 - Stalk Harvest, Kenaf Demonstration Farm,
Zambia



Photo 27 - H. cannabinus Stalk Harvest with Tractor
Side-Mounted Cutter Bar, Zambia



Photo 28 - Machine Ribboning of
Kenaf, Stalk Feeding, Zambia



Photo 29 - Machine Ribboning of Kenaf, Bast Ribbon
Delivery, Zambia



Photo 30 - Bast Ribbon Spread on Drying Lines,
Zambia



Photo 31 - Bast Ribbon Field Bale,
Zambia



Photo 32 - Bullock Cart Transport of Retted Kenaf
Fiber "Field Drums", Thailand

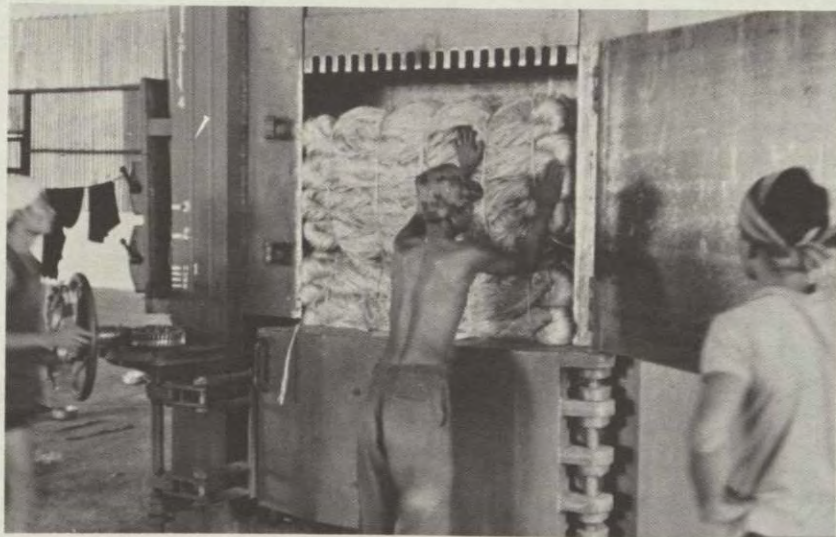


Photo 33 - High-Density Baling of Retted Kenaf
Fiber, Thailand



Photo 34 - Truck Transport of High-Density Kenaf
Fiber Bales, Thailand



Photo 35 - Research Trial Planting with 6-Row
Planting Rake and Seed Dibbling, Zambia



Photo 36 - N.P.K. Factorial Trial, H. cannabinus,
Zambia



Photo 37 - Kenaf Variety and
Time-of-Planting Trial,
100 Days Old, Zambia



Photo 38 - Cross-Pollination, H. cannabinus, Zambia



Photo 39 - Usable Stalk Weight Research,
H. cannabinus, Zambia



Photo 40 - Ribbon Yield Research, H. cannabinus,
Zambia

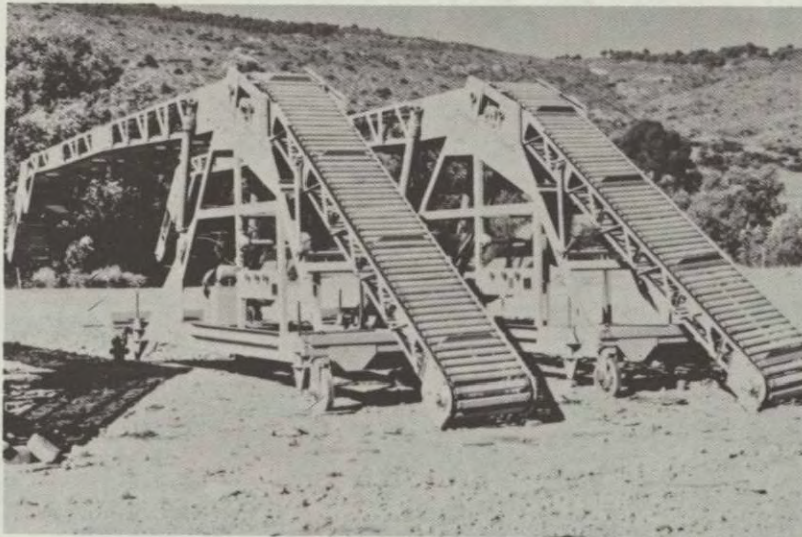


Photo 41 - Inclined Mobile Stackers for Baled
Nonwood Plant Fiber

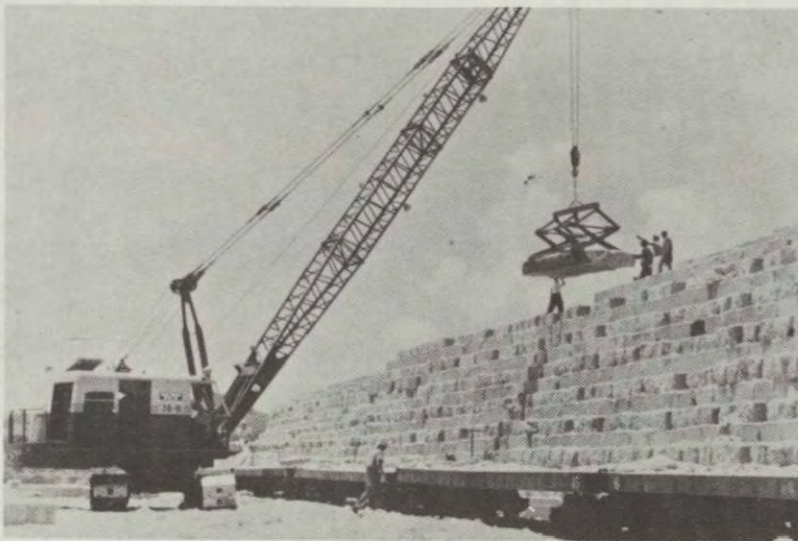


Photo 42 - Heavy Duty Crane Stacking Nonwood Plant
Fiber Bales in Mill Storage Yard



Photo 43 - Positioning Nonwood Plant Fiber Bales
by Hand on Partially Completed Stack

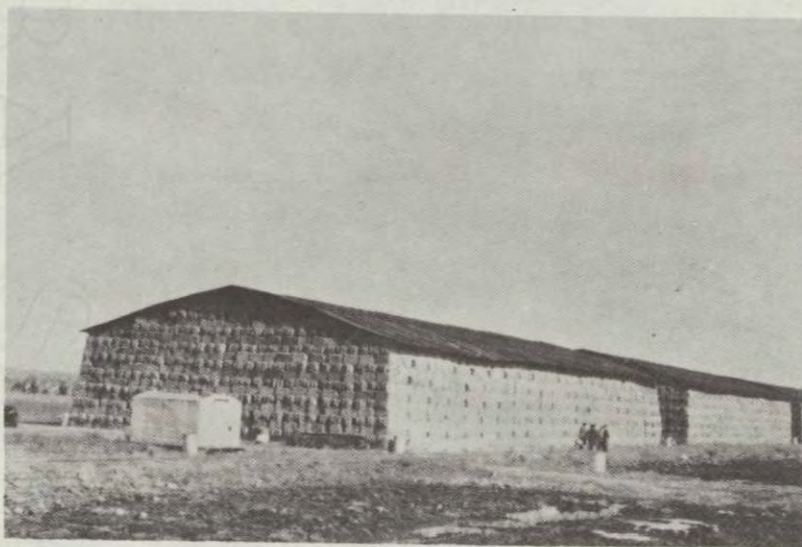


Photo 44 - Covered Bale Storage of Nonwood
Plant Fiber



Photo 45 - Ritter Bulk Storage of Nonwood Plant Fibers with Pulp and Paper Mill in Background

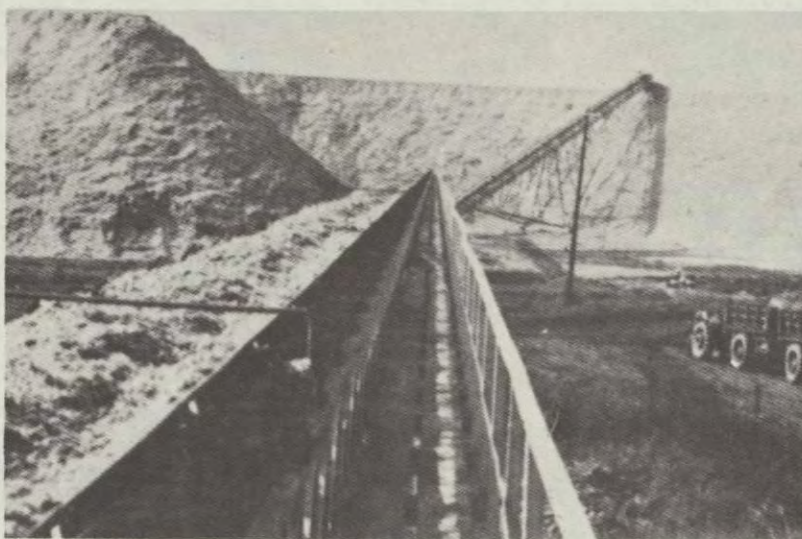


Photo 46 - Moist or Wet Bulk Storage of Nonwood Plant Fibers Using Circular Stacker



Photo 47 - Bale Feed to Shredder and Wet
Cleaning System



Photo 48 - Feed of Loose Whole Stalks
to Shredder



Photo 49 - Hydrapulper for Wet Cleaning
Shredded Fiber

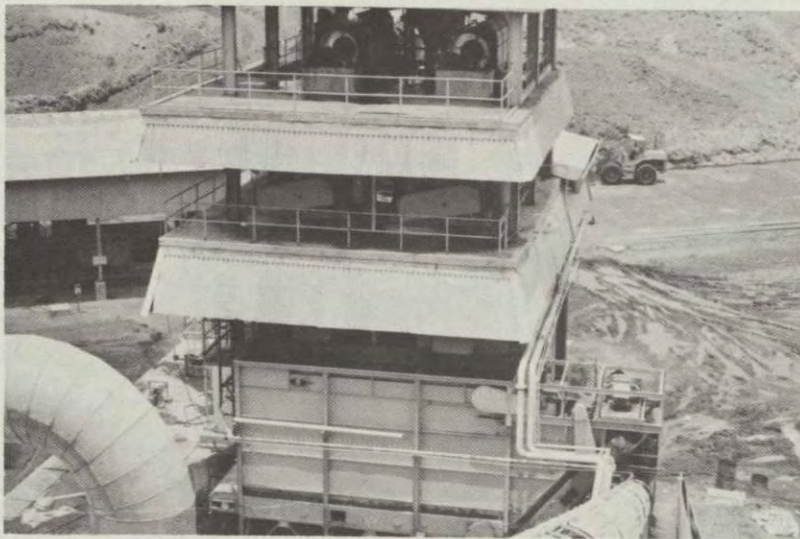


Photo 50 - Wet Cleaning Plant for Nonwood Plant
Fibers with Live Bottom Bin

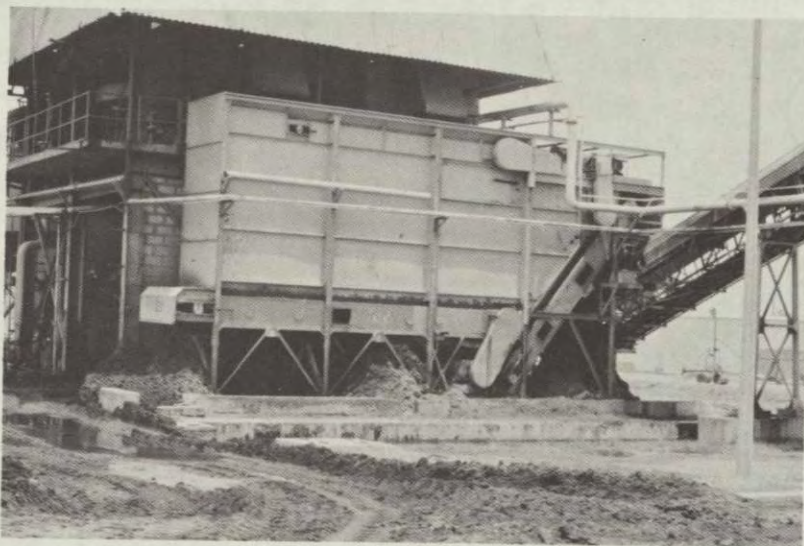


Photo 51 - Live Bottom Bin Feeding Belt Conveyor
to Digester



Photo 52 - Belt Conveyor for Cleaned Fiber to
Digester with Blowtank in Foreground

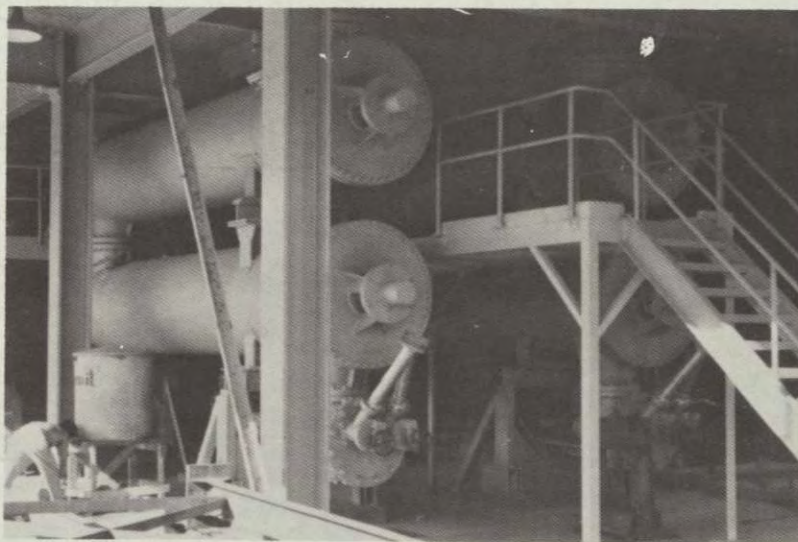


Photo 53 - Horizontal Tube Continuous Digester

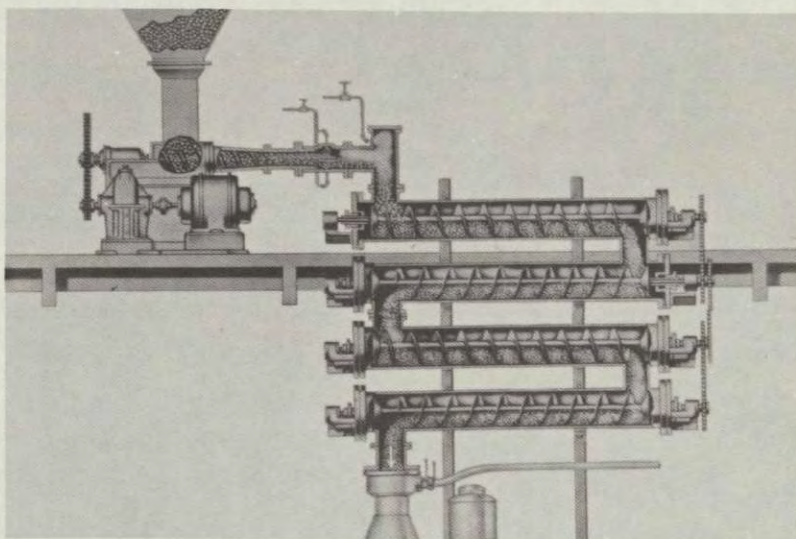


Photo 54 - Horizontal Continuous Digester
Showing Screw Feeder and Discharger

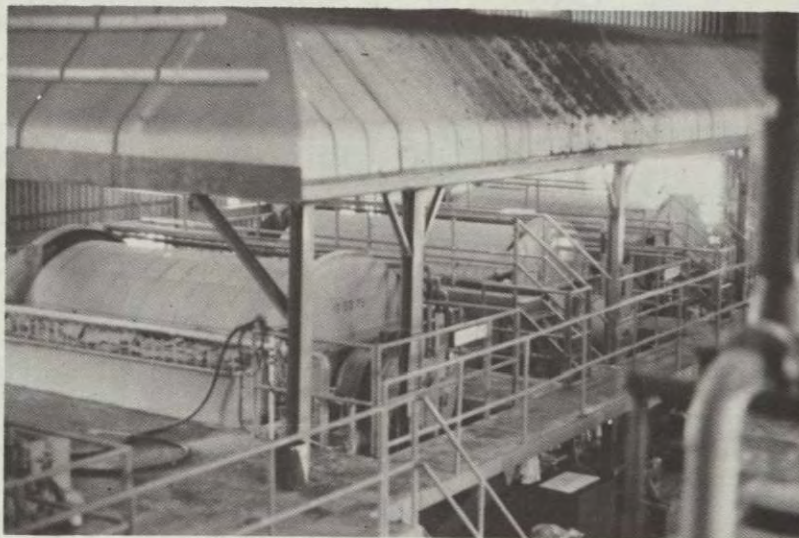


Photo 55 - Unbleached Pulp Washers

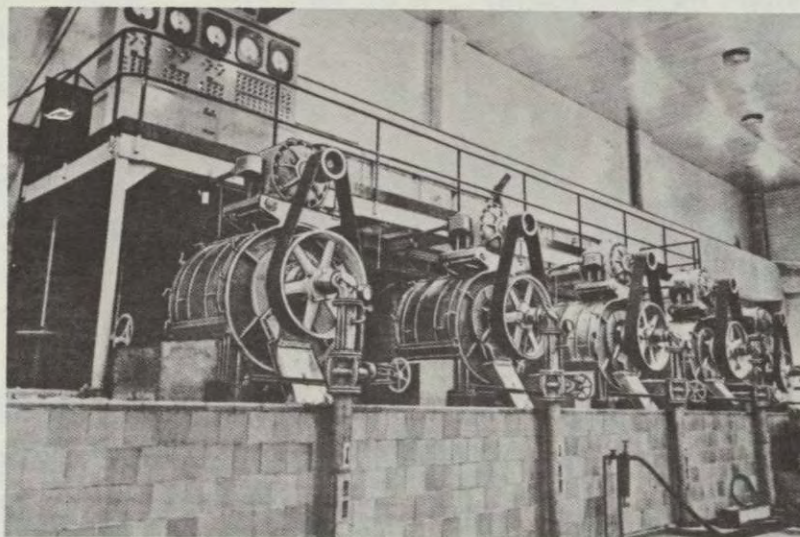


Photo 56 - Bank of Centrifugal
Pulp Screens

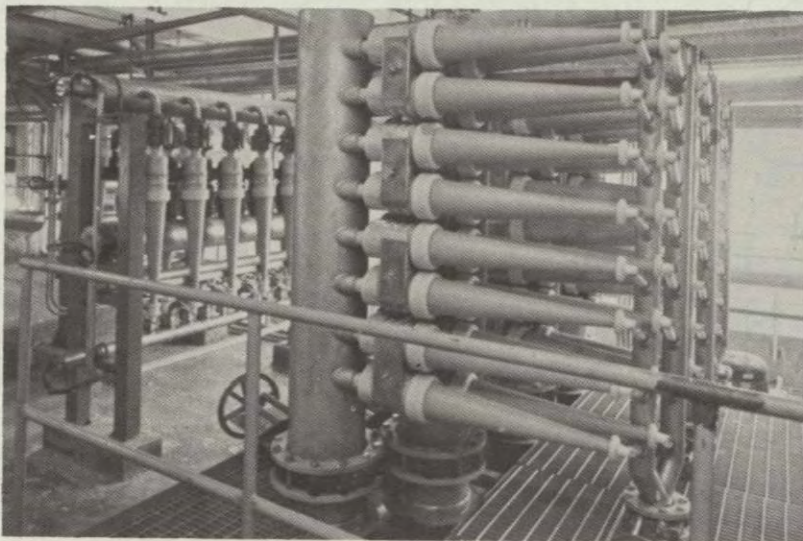


Photo 57 - Centrifugal Pulp Cleaning Installation



Photo 58 - Bleach Plant Washers

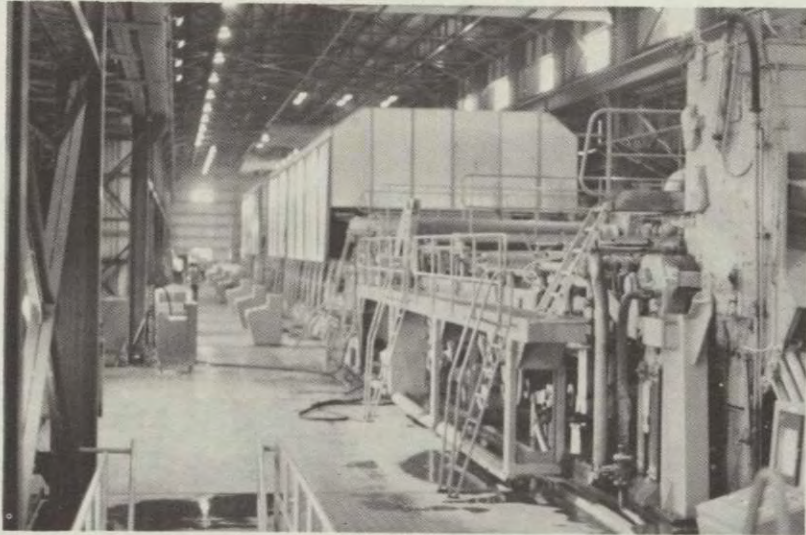


Photo 59 - Pulp Forming and Drying Machine

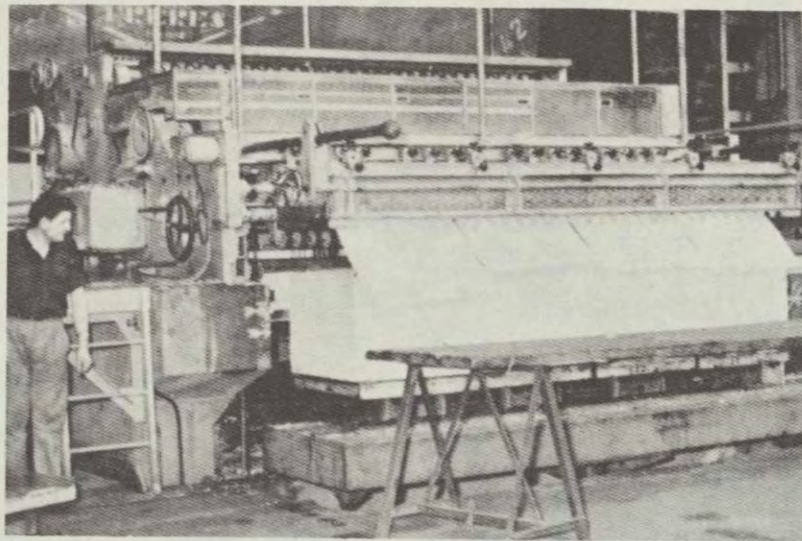


Photo 60 - Pulp Sheeter

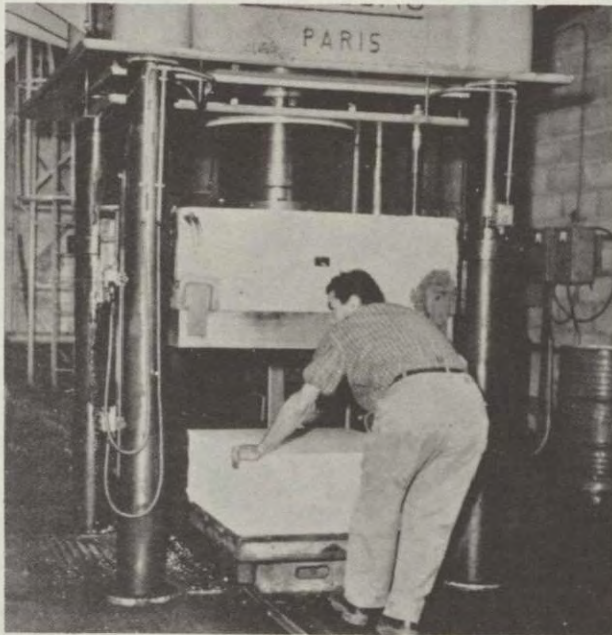


Photo 61 - Pulp Bale Press

Photo 62 - Wrapping and
Tying Pulp Bales

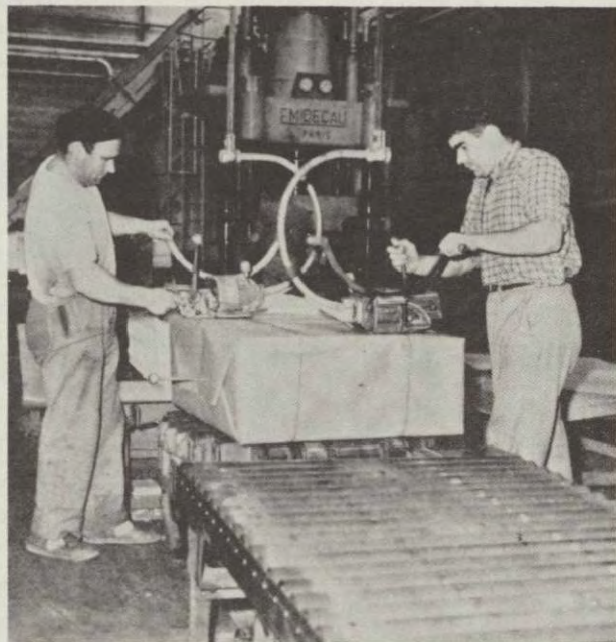




Photo 63 - Handling and
Loading Pulp Bales
for Shipment

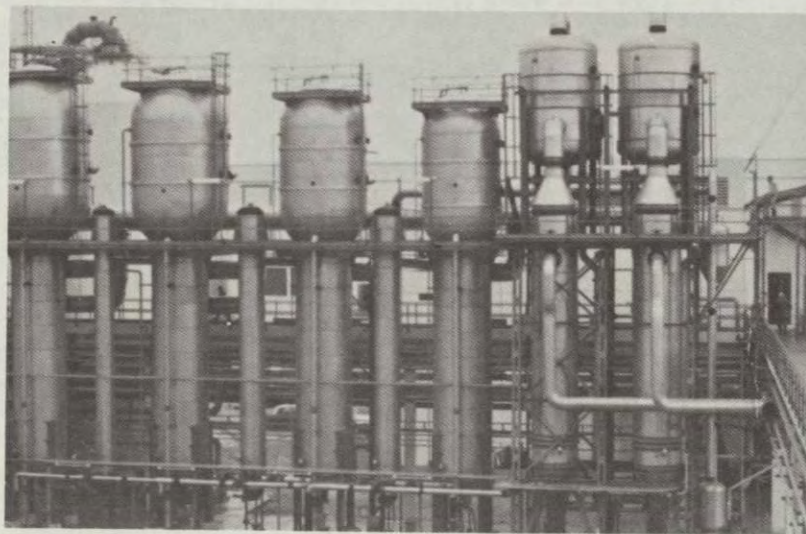


Photo 64 - Multiple Effect Evaporators
for Black Liquor

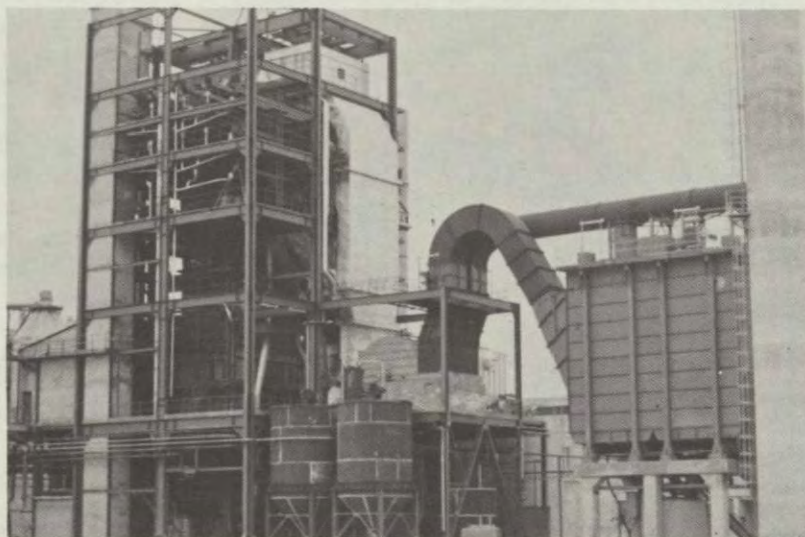


Photo 65 - Recovery Boiler, Cascade
Evaporator, Precipitator and Stack



Photo 66 - Lime Kiln and Reausticizing
System

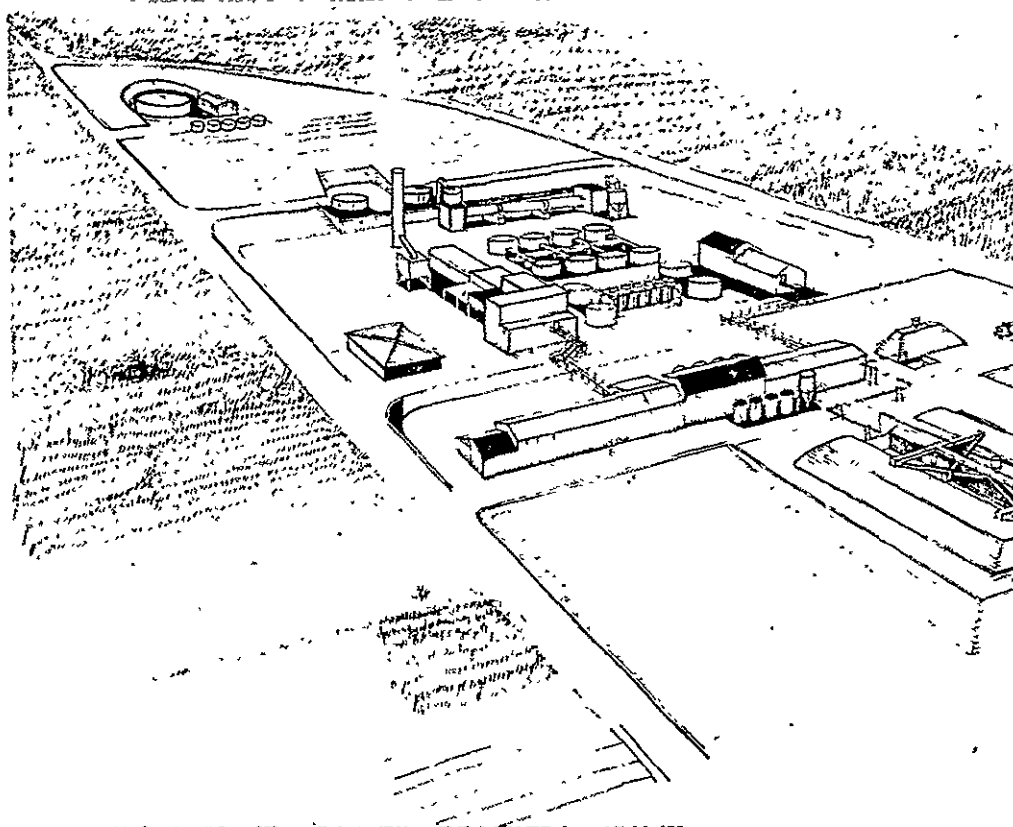


Photo 67 - Panoramic View of Proposed Kenaf
Paper Pulp Mill for Mekong Basin Area

CHAPTER VI - THE HANDLING, STORAGE, RECLAIMING, FIBERIZING,
AND WET CLEANING OF KENAF AT THE PULP MILL

1. Introduction

It has been widely recognized by the various investigators of kenaf for paper pulp that, as is the case for most other agricultural residues which result from harvesting crops on a seasonal basis, kenaf storage in large quantities sufficient for year around operation of a large pulp mill will have to be carefully planned. As reviewed in Section 2.5. of Chapter I of this Study, most of the research on kenaf raw material storage has been on relatively small sized samples to determine the effect of various storage environments and chemical treatments on the preservation of yield and pulp quality for both green and field dried kenaf brought to the mill yard for storage for periods of eight months or longer.

It does appear however that there are sufficient research data on the results of storage of kenaf which, when combined with the knowledge on the storage of other agricultural residues such as bagasse and straw that are used for paper pulp, will facilitate the preliminary outlines for the several fibrous raw material storage and handling systems that could possibly be employed at the kenaf paper pulp mill. The system of storage and handling to be employed at the kenaf pulp mill storage yard would of course be dependent upon the form in which kenaf fibrous raw material is hauled to the mill.

2. The Handling of Green and Field Dried Whole Stalk and Bast Ribbon Kenaf Brought to the Mill in Bulk or Bundled Form

There will be some green and field dried whole stalk and bast ribbon kenaf in either chopped or bundled form that will be hauled to the mill directly from nearby farms where transport in these high bulk forms would be economical. The amount of this kenaf accepted by the mill on a daily basis would not exceed the daily requirements of the mill so that none of this bulky material would have to go into storage as is or be prepared for long term storage by baling the field dried stalks at the mill or preparing the kenaf for bulk storage. It is believed that such a scheduled program to use the kenaf grown near the projected mill and within the zone of low enough transportation cost for bulk hauling will allow utilization of this kenaf supply within the season of harvesting green and then dry stalks up until deterioration in the field of the kenaf for pulping would begin.

All kenaf hauled directly to the mill would be weighed in the conveyance by difference and dumped or piled directly onto storage conveyors so that the material could be spot tested with moisture meters or sampled for moisture tests and fed as desired onto main conveyors feeding kenaf to the bale breakers followed by cutter-fiberizers ahead of the fiber wet cleaning system. It would be understood that for bundled or loose material, whole stalk kenaf only would be accepted on days when that grade of pulp was being run and bast ribbon would be accepted only during that production time. The feeding of material similar to loose whole stalk kenaf to a shredder is shown in No. 48 of the pulp mill photographs at the end of Chapter VII of this Study.

3. The Handling and Storage of Field Dried Whole Stalk and Bast Ribbon Kenaf Bales at the Pulp Mill

Bales of field dried whole stalk or bast ribbon kenaf brought into the pulp mill yard would be weighed and then would either be used directly or placed in storage. When used directly, the bales would be dumped or removed from the trucks onto the storage conveyors and broken apart for moisture checking or sampling for moisture tests before being conveyed into the bale breakers. A typical system for feeding the bales to a bale breaker and shredder is shown in No. 47 in the pulp mill photographs in this Study.

When a shipment of bales would be received to go into storage, the bales would be weighed and a number of bales scattered uniformly throughout the shipment would be selected for moisture tests. After sampling for moisture tests or testing for moisture directly, the selected bales used for the tests would be dumped onto the conveyors for processing that day preferably or rebaled for storage.

The systems for handling and storing and reclaiming the bales of field dried whole stalk and bast ribbon kenaf would be similar to some of those which have been used for bales of other nonwood plant fibers such as bagasse and straw. Atchison (33,34,35) has described the following systems:

The Classical Celotex Method of Bale Storage

The procedure developed and patented for the Celotex Corporation in Louisiana has been in successful use for more than 40 years. Bagasse at approximately 50 percent moisture content is baled with heavy duty equipment and the bales of a specific size are stacked in an optimum pattern allowing sufficient air circulation during the drying out period so as to minimize localized overheating in the stacks due to the fermentation reaction to acetic acid of the residual sugar in the bagasse. This fermentation takes place and provides heat sufficient to dry the bagasse to less than 25 percent moisture content within a few months. The outside of the stacks can be treated with boric acid as a preservative and the stacks covered with reusable asphalt coated metal sheets. The Celotex method of stacking the bales with a heavy duty crawler type crane equipped with a long boom and a special grab to pick the bales up off a truck is shown in No. 42 and a typical bale stack is shown in No. 44 of the pulp mill photographs of this Study. The same crane is later used to remove the bales from the storage piles and to load them on dump trucks for hauling to the bale storage conveyors for processing. In the case of field dried kenaf of only about 12.5 percent moisture

content, the stacks could be built without the pattern allowing for air circulation within the pile because of the low moisture content in the bales. Covering of the stacks of kenaf bales would probably not be required except for those which would be carried through the rainy season.

Mechanical Handling of Bales

Where there is a shortage of labor or the cost of labor is high, a highly mechanized system of bale handling into and out of storage can be used. This has been described by Toups (218). While this system would be suitable for kenaf bales, in an area of plentiful and low cost agricultural labor where the Mekong project kenaf pulp mill would be located, such a system would not be required and would not be economical to use.

The Taiwan Method of Bale Handling and Storage

This system of bale storage has been developed by the Taiwan Sugar Corp. and the Taiwan Pulp and Paper Corp. for use on bagasse containing 40 to 45 percent moisture and is economical for areas where labor costs are low. Small bales that can be handled by one man are brought to the mill yard and transferred by hand to individual buckets on a bucket stacker riding on rails along the stack. This elevates the bales above the top of the pile and dumps them on a flat belt conveyor reaching out over the stack and from which the bales are removed by hand and placed properly in the stack. By building several large stacks simultaneously one layer at a time during the dry season, the small bales rapidly dry out resulting in quick dissipation of heat and evaporation of the acetic acid formed by fermentation of the residual sugar. The stacks are then covered with straw matting that sheds rain. A stacker similar to the type used in the Taiwan system is shown in No. 41 of the pulp mill photographs in this Study.

The Thessalian Method of Bale Handling

Thessalian Pulp & Paper Industries, Ltd., in Greece uses a very satisfactory method of unloading bales of straw and placing them on top of the stack. The transporting vehicles are provided with false bottoms made of seamless steel tubes and flat irons welded together to form a grid with steel tackles fixed at the outer edges. A large mobile crane with a long boom carries a top rack matching the size of the false bottom and cables with terminal hooks hanging from it so

that the false bottom loaded with straw can be lifted up when they are attached. The load of bales is lifted to the top of the stack and the false bottom is unhooked on one side so the crane can pull the false bottom out, thereby tumbling the bales out over the top of the stack. The bales are then arranged manually by workers on top of the stack. Misra (217) has described this system in detail and claims this is a superior procedure as compared to using the portable bale stacking elevators.

In the storage yard for the projected mill, bales would be retrieved from storage using the mobile crane with long boom and a large bale clamp or by sliding the bales down an inclined chute into a truck or a dump truck for hauling to the storage conveyors. In planning the labor force for the pulp mill kenaf bale storage yard, the Consultants have estimated that a total of 320 persons would be employed in that area of the mill because of the expected high usage of manual labor in stacking and handling the bales.

4. Alternative Systems Considered for Bulk Storage and Handling of Kenaf at the Pulp Mill

In the case of the Mekong project kenaf pulp mill, it does not appear that a bulk storage and handling system in the mill yard would be as economical as or any more satisfactory than the bale storage systems for field dried kenaf which have already been discussed. There is not even a remote possibility that long term bulk storage systems would be employed at the satellite collection points for kenaf because of the relatively small quantities involved at each location, the low cost of labor, and the necessity to reduce transportation costs by hauling only high density bales of field dried material for any appreciable distance to the pulp mill.

There are, however, a number of very satisfactory systems that have been developed for bulk handling and storage of bagasse for pulp manufacture or fiberboard. These could be used for kenaf when warranted by a high cost for labor or the growing of the crop on large farms with mechanized harvesting and transportation of the raw fiber material to the mill in bulk.

It should be noted that there is one very important technical advantage of the bulk storage systems where the fibrous raw materials are placed into storage in wet or moist form, rather than at the low moisture content of 12.5 percent that field dried kenaf is expected to contain. That is the fact that in the drying out as in the storage of bagasse in bales or bulk form starting out at about 50 percent moisture, the fermentation reaction destroys most of the residual sugar in the fiber and it, therefore, lessens the amount of oxygen-consuming organic material which enters the effluent from the fiber wet cleaning system. This same result occurs when wet bulk storage or ensilage systems are used for the fibrous materials containing fermentable carbohydrates. However, this particular advantage is nullified if the wet cleaning system effluent can be used for irrigation purposes without any treatment so that these wastes can be returned to the fields.

A number of these bulk storage and handling systems for bagasse have been described by Atchison (33,34,35). The major ones which would be applicable to kenaf, preferably after chopping and or fiberizing, are as follows:

The Ritter Biological Process for Storage of Nonwood Fibrous Raw Material in Bulk

The first successful wet bulk storage system for bagasse was that developed by the late E.A. Ritter and his collaborators in South Africa.

In this system, the moist depithed bagasse from the sugar mill is mixed in a slurry with a recycled solution containing a specially developed biological fluid and the suspension is flushed to a bulk storage area through elevated channels or a pump-up device. A small amount of molasses is added continuously to fortify the recycled bacteria culture solution to saturate the bagasse so that, when it is subjected to anaerobic storage conditions in the densely compacted pile of fiber, there is a formation of lactic, rather than acetic, acid so that the cellulose fibers are preserved to maintain yield and strength properties of the pulp over an extended period of storage. The storage area is a receiving slab of concrete coated with epoxy resin or of special asphalt on compacted earth, traversed in one direction with parallel channels which are provided with removable slotted wooden covers through which the recycled solution draining from the pile of bagasse can be reclaimed. When the wooden covers are removed from the channels, the bagasse can be removed from the pile with a bulldozer and end loader and dumped into the channels so that a recycled stream of water can convey the fiber to a dewatering device followed by a wet depithing machine for the final stage in fiber cleaning before the digestion. This method of storage or variations of it are in successful use in South Africa, Argentina, Brazil, Mexico, and Iran and it is being considered for bagasse pulp mills, in other parts of the world.

There are many advantages to the Ritter system and some of the other wet bulk storage systems as compared to baled storage for the nonwood plant fiber raw material and most of them would apply to the storage of both kenaf whole stalk or bast ribbon, preferably after it is chopped and, in the case of the whole stalk, fiberized as well. They are (a) the elimination of the troublesome baling wires, (b) the elimination of the fire hazard which bales create, (c) the elimination of dust problems with attendant respiratory complications for the workers, (d) a decrease in labor required in the fibrous raw material storage yard, (e) the storage of a large quantity of fibrous raw material in a relatively small area due to the high density of the piles formed, (f) a more easily cleaned fiber in the wet cleaning system where pith, fine fibers, and residual soluble organic materials would be separated, and (g) a lowering of the chemical consumption in cooking and bleaching the pulp. Overall, the use of this type of storage system results in the highest quality of pulp that can be produced from the nonwood plant fibers. Unlike some of the other wet bulk storage systems, once the pile is formed in the Ritter system there is no further wetting necessary through the storage period. The Ritter storage system for a large bagasse pulp and paper mill is shown in No. 45 of the pulp mill photographs in this Study.

The International Paper Co. Wet Storage System
in Puerto Rico

Due to the development of a respiratory ailment, bagassosis, by personnel handling bales of bagasse, this mill changed to a wet bulk storage system. Bagasse from the sugar mills was slurried in a tank and pumped through portable pipes to a storage area. The storage field was not paved but was merely compacted and graded to a slight slope. Once the bagasse pile was started, it was shaped by bulldozers and heavy duty front-end loaders. As there was no biological pre-treatment, as in the Ritter system, it was found necessary to keep sprinkling the pile with water throughout the storage period. In order to keep the pH of the fiber in the pile neutral, it was not possible to recycle the water used on the pile because of the acetic and other acids and odors formed. At one time, spent black liquor that would have gone into the river anyway, as the mill had no recovery system, was sprayed on the pile but this was considered something that would not be continued as a normal practice due to lignin precipitation on the fiber resulting later in higher consumption of cooking chemical. The fiber was reclaimed from the piles with bulldozers and front-end loaders and metered through two twin drum feeders onto a sunken belt conveyor.

Methods of Storing Fibrous Raw Materials at Valentine Pulp
and Paper Company in Lockport, Louisiana

Because of severe losses from baled bagasse stored at high moisture content, this company developed a storage system at the sugar mill for the freshly milled bagasse without pre-treatment of any kind. The fiber was carried on a belt conveyor from the plant to a rotating type belt stacking conveyor which makes a large doughnut-shaped pile open at one place for conveyor entry. A picture of one of these piles is No. 46 of the pulp mill photographs in this Study.

This system was not very expensive to install, it required only one man to operate it, and it did not require very much power; the outside layers of fibrous material suffered considerable deterioration but did form a protective layer for preserving anaerobic conditions in the bagasse below the outer surfaces of the pile.

After the raw bagasse was stored at the sugar mill for some time without any treatment, it was then reclaimed from the piles with a large crane with clam-shell bucket and transported to the pulp mill where it was moist depithed and part of it conveyed out onto a yard for storage. Here bulldozers and front-end loaders were used to build a pile and it was soon found that storing the fiber again after

re-aerating it in the moist depithing operation resulted in a rapid rise in temperature in the pile that had to be reduced by wetting the pile to prevent degradation of the fibrous raw material. By implanting thermocouples in the pile, the development of high temperatures could be observed and reduced by spraying water on top of the affected area from a portable network of plastic hoses with spaced rotating sprinkling nozzles. While this system is satisfactory, it is now being changed to use a rotating stacker with a wetting device to add water to the bagasse as it is placed in the pile because of the high cost of using the mobile equipment for spreading and compacting the fiber on the piles.

Wet Bulk Storage System Adopted by the Celotex Company

This company has in recent years replaced the successful bale storage system in use for many years with a wet bulk storage system based on the use of the rotating belt stacker also used by Valentine. The bagasse is carried to the stacker on a conveyor or for greater distances by a Rader pneumatic system. Nozzles spray water on the bagasse as it leaves the stacker and falls on the pile and the stacker is continually rotated around the pile so that the water drains uniformly down through the pile at frequent intervals. Early experiments showed that the use of solutions of chemicals, such as propionic acid and lime, which would be expected to have an inhibiting effect on an adverse microbial action under acid conditions, was less effective and economical than the use of water alone when the pile is sprayed completely around on almost a daily basis:

Although the area travelled by the stacker and the trucks hauling the fiber away from the piles are paved, the actual areas covered by the piles are not. The fiber can be reclaimed from the piles with cranes equipped with clam-shell buckets loading trucks or with bulldozers and front-end loaders pushing it onto a belt or drag conveyor or into a flume for transport to the wet cleaning system.

Thus, it can be seen that, if the necessity arises for a substitute wet bulk storage method for the bale storage methods which the Consultants judge to be best for kenaf for the Mekong pulp mill project under present circumstances, there are already several successful systems being used on bagasse which can be readily applied to the storage and handling of kenaf. It would appear that, because of the information already available on wet bulk storage systems for bagasse, there will be only a limited amount of practical research needed to adapt such equipment and concepts to the storage of kenaf.

5. The Handling, Fiberizing and Wet Cleaning of Kenaf
in Preparation for the Digester

With the exception of fiberizing, which has already been done at the sugar mill in the case of bagasse, the process that would be recommended for preparation of the raw kenaf fiber for cooking would be identical with that used in modern installations where nonwood plant fibers are pulped. An outline of the system as it would be built for handling kenaf is given in the flowsheets at the end of Chapter VII of this Study.

The baled kenaf, either bast ribbon or whole stalk, would be conveyed to a shredder in which would be incorporated a chopping unit that would also serve for further reduction in length of any kenaf that had previously been chopped before baling. The shredding equipment designs would be any one of a number of several types which are in commercial use to prepare sugar cane for the sugar extraction process. Shredding places the bagasse in a form facilitating separation of the pith and the fiber suitable for papermaking and similar, but to a lesser effect, beneficial results would accrue from the use of shredding as a step in kenaf fiber preparation.

After the mechanical preparation of the kenaf fiber, it would be conveyed to the Hydrapulper and made into a slurry with recycled water. This would result in washing of the fiber to dissolve soluble sugars, gums, waxes, etc. and to facilitate removal of parenchyma cells, fiber fines and dirt in following operations.

From the Hydrapulper, the kenaf slurry would be pumped through a low gravity centrifugal cleaner to separate out any sand, rocks, or other heavy particles that would result in severe mechanical abrasion of machine elements further on if not removed.

The kenaf slurry would then be dewatered in a rotary or vibrating flat screen drainer and the fiber fed into a centrifugal hammermill-type apparatus similar to a bagasse depither for removal of further quantities of fine solids and for final dewatering of the fiber preparatory to the cooking step.

The wet cleaned kenaf fiber would then be conveyed directly to a live bottom bin or dumped out on a surge pad as necessary during breakdowns, changes in operating rates, etc. A front-end loader would be used to push the kenaf from the surge pile onto a conveyor to the live bottom bin as required.

The flow of kenaf from the live bottom bin would be controlled by adjusting the speed of the live bottom elements and a metering roll at the outlet. A slight excess of kenaf would be conveyed to a more positively controlled twin pin wheels metering device to the digester feed conveyor with the excess being returned to the live bottom bin. Tramp metal would be removed by a self-cleaning electromagnet above the belt and the amount of kenaf being fed to the digester would be measured by a weightometer.

Pictures of some of the major pieces of equipment for the process described are Nos. 47 through 54 in the pulp mill photographs as titled.

The rest of the flowsheets show the processing of kenaf through the pulp mill, bleach plant, drying machine, and bleached pulp bale finishing system, and additional photographs show the chief items of equipment including the recovery system. As these are standard pieces of equipment and processes known throughout the industry, description of them is not warranted for this Pre-Feasibility Study.

In closing this description of the kenaf fiber wet cleaning system, mention needs to be made of the white water that is recycled for washing the fiber in the Hydrapulper. This can be recycled only a few times due to the fermentation of the sugar and the buildup of organic acidity and solubles in the solution and then it has to be dumped or bled off continuously into the effluent system. Before each recycle of liquid to the Hydrapulper, the fibrous fines and pith should be removed because it is desirable that they have no further contact with the acceptable fiber. This separation can be achieved and the waste fiber thickened by means of clarifiers, drum filters, rotating dewatering screens, side-hill screens, or other similar purpose equipment. The waste fiber can also be further dewatered to higher consistency for hauling out for landfill or for burning in the boilers by means of presses or centrifuges. More suitably, the excessive load on the effluent treating system the waste water from this area of the mill would produce would be best eliminated by using it for irrigation of crops on farms near the mill.

CHAPTER VII - THE UTILIZATION OF KENAF FOR THE MANUFACTURE OF PAPER PULP IN THE MEKONG BASIN PROJECT MILL

1. Introduction

In Chapter I of this Study, a comprehensive historical review has been given of the published data from work that has been carried out all over the world on the harvesting, transporting, and storage of kenaf and its utilization, specifically for pulp and paper. In addition to this literature review, discussions were held by the Consultants with leading workers in this field in the United States and at the USDA and there was correspondence with technical experts in the laboratories overseas that were known to be studying the pulping of kenaf.

As a result of this extensive review and the discussions of kenaf pulping with these very cooperative scientists, the Consultants have made some important findings and arrived at some definite conclusions as to the optimum processes needed for the utilization of kenaf for the manufacture of paper pulp in the Mekong Basin project mill. These conclusions are also backed by the knowledge and experience gained in the raw material preparation and the pulping of other nonwood plant fibers of all types in commercial operations. These techniques, where applicable, are expected to be used for the production of paper pulp from kenaf.

2. The Harvesting, Transporting and Storing of Kenaf for the Mekong Basin Project Paper Pulp Mill

The harvesting of kenaf bast fiber and whole stalk kenaf for paper pulp has been reviewed in Chapters I and V.

In developed countries and in developing countries with a shortage of labor and high labor costs such as Iran and Algeria and where kenaf can possibly be grown successfully in large plantation areas, there is no doubt that the harvesting system will have to be almost completely mechanized, if kenaf is to compete economically as papermaking fiber with wood or already collected agricultural residues such as bagasse and with other mass-produced annual crops used for other purposes. Such mechanized harvesting systems can be expected to be similar to those used for sugar cane or forage harvesting. Similarly, large capacity cross-field, highway, and/or rail line transport systems would be employed for kenaf. Large wet or dry bulk storage systems of the type used to store ensilage or agricultural residues such as bagasse would be used under optimum conditions to provide a year around supply of uniformly preserved fibrous raw material.

For the Mekong Basin area with its traditional small farm holdings and a plentiful and low cost supply of labor, the use of sophisticated harvesting machinery for either ribbon or whole stalk kenaf would not appear to be practical or economical. Although easily portable field ribboning machines may eventually find application for the project requirements envisioned in the agro-economic sections in this Study, it is believed that, in the pre-feasibility analysis, the harvesting system must be based almost completely on the farmer manually cutting the stalks and either delivering them as such or stripping the bast ribbon from the stalks by hand prior to delivery. In either case, the material would have to be delivered in field dried condition. The farmer would transport the ribbon field bales or stalk bundles by cart to the pulp mill or the nearest collection center or baling station. From the collection centers, the transport would be by short haul truck to the baling station where the dry kenaf would be baled and then stored or hauled directly to the pulp mill in trucks for processing or storage there. The only exception to this system of handling would be from areas nearby from which the farmers could haul green or field dried kenaf ribbon or whole stalk directly to the pulp mill for processing on a daily basis.

As to the woody core material remaining after the bast ribbon is stripped from the stalk, for the present Study in determining pulp manufacturing costs it is assumed that this material will be left at the farm. At the same time, it is recognized that, under special circumstances, this fraction of the kenaf stem could be valuable for the manufacture of mechanical, thermomechanical, chemimechanical, or cold soda pulps, usable for up to 85 to 90 percent of the furnish for newsprint and in low cost printing and writing papers of the grades which usually contain groundwood. It could also be used practically 100 percent for the manufacture of semi-chemical pulp for corrugating medium. Other uses would be for fiberboard and particleboard and for charcoal and the manufacture of chemicals such as furfural and xylitol. In addition, when the economics are favorable, the woody core material can be utilized for its fuel value by the pulp mill as discussed in Chapter I, Sections 4.2. and 4.3.

3. The Expected Effects of Storage Conditions on Yield and Quality of Kenaf Paper Pulps in the Mekong Basin Project Mill

The several procedures studied and found suitable for storage of kenaf for paper pulp have been reviewed in detail in the subdivisions of Section 2.5. in Chapter I of this Study. There is no question but that the necessary year around storage of either green or field dried kenaf under conditions which will preserve the cellulose and paper-making fiber so as to maximize yields and pulp physical strength properties is a most important step of the fibrous raw material preparation for the pulp mill.

In the review of the technical literature for this Study, it was found that there are confusing and conflicting data reported relative to the overall yield of bleached pulp that can be expected from either whole stalk material or bast ribbon from kenaf. In general, yields for the whole stalk material have been reported all the way from 30 percent to more than 40 percent. Likewise, reported yields of bleached pulp from the ribbon material have varied from as low as 35 percent to as much as 55 percent. It has been found that, in most cases, the higher yield values given were based on the actual oven dry weight equivalent of the kenaf fed to the digester and the oven dry equivalent weight of pulp after bleaching. However, it was surprising to find that, while the figures are correct when clearly defined and understood, they would be very misleading if it were necessary to establish the numerical relationship of overall yield between the field yield of the green kenaf stalk at maturity or time of frost kill and the yield of bleached pulp off the end of the pulp dryer. There were also found cases where abnormally high digester yield values were reported. It was obvious, even when the researcher had not pointed it out, that a wet cleaning at the pulp laboratory or leaching in the field after maturing of the kenaf stalks with consequent loss of water soluble material and some fines before the digester must have caused this discrepancy.

These inconsistencies in yield values indicate that this confusion of yield data should be cleared up and considered on an overall basis defined by a statement from the researcher of the history of the treatment and storage of the kenaf from the time the stalk matures or is frost killed until it is made into finished pulp. In addition, such overall yield values must take into consideration and include any microbial or physical loss of raw papermaking fiber in storage, mechanical losses in handling and transporting, the losses of solubles and fines in wet cleaning, and the actual losses at every step of the process in the pulp mill to the end of the pulp drying machine.

The USDA has shown that, when the kenaf matures, the stalk dry solids equivalent weight contain up to 25 percent of water soluble organic matter such as gums, sugars, waxes, etc. They found that, with satisfactory long term wet bulk storage systems for the green kenaf followed by wet cleaning the raw fiber before pulping, most of this soluble or fermentable nonfibrous material never reaches the digester. This gives a high yield of pulp across the digester but the overall yield for whole stalk bleached pulp is calculated to be about 30 percent of the original solids in the frost killed or mature stalk. For the bast ribbon, the overall yield of bleached pulp is about 40 percent of the original dry solids in the kenaf ribbon when stripped from the green stalk.

In the cases where the kenaf stalk is allowed to stand in the field after a killing frost or after it matures or where the ribbon is field dried for a prolonged period, the leaching out of water solubles by the rain results in a higher digester yield being reported than would have been obtained if the original green kenaf had been pulped. Admittedly, although the overall yield value may not be clear in this case and is obviously lower than the digester yield, the weight of the leached, field dried kenaf is the basis on which it is purchased from the farmer rather than as the kenaf stands at maturity in the field before any of the solubles are lost. For kenaf stalks subjected to field storage and leaching by rains, bleached pulp yields of over 40 percent have been reported. Bleached pulp yields have also been reported higher than 50 percent for the ribbon when most of the leachable solids had been removed in field drying. But it must also be kept in mind that these yields are based on the oven dry equivalent weight of fiber fed to the digester.

Once the causes of these discrepancies in overall yield data that have been reported were clarified, it was concluded that the historical conditions, depending upon the weather, rains, time of harvest, etc., could vary between the extremes of complete retention of the water solubles in kenaf up until the time it went to the digester to their practically complete removal during prolonged field storage and drying periods when leaching by rain or other physical changes reduced them. The latter effects would take place much of the time before the farmer could sell his kenaf to the collection station on an oven dry weight equivalent basis, or a field dried basis proportional to that.

Therefore, for making the agro-economic estimates of the growing areas needed and costs for producing kenaf whole stalk and bast ribbon pulps in the Mekong project mill, it has been assumed that the average overall yield of bleached kenaf whole stalk pulp will be 35 percent on an oven dry equivalent basis of the raw material as purchased from the farmer. An overall yield of 45 percent has been used for the bast ribbon on the same basis. In addition, in choosing these overall yield values as a reasonable compromise, where the kenaf field dried fibrous raw material will be supplied to the pulp mill in bales, full weight and consideration have been given to all the processing losses which would occur in a commercial pulping operation for which the kenaf fiber had been wet cleaned before the digester.

From the standpoint of any possible detrimental effects of handling and storage conditions on the quality of the pulps that would be produced in the project mill, it appears that the system of baling field dried kenaf whole stalks and bast ribbon and storing the bales in covered ricks at the satellite storage areas at the baling stations or at the pulp mill, as developed in the agro-economic sections of this Study, will be completely satisfactory for preserving the papermaking fiber for year around operation of the pulp mill.

However, this does not mean to imply in any way that wet or dry bulk storage systems for kenaf, as are used successfully for bagasse, would not also result in an equally satisfactory supply of fibrous raw material from the pulping standpoint and yield of pulp. However, with the economic and labor situations existing that will make it possible to supply either form of the kenaf fiber to the Mekong project pulp mill, the system of storage in covered ricks for the field dried kenaf bales would be favorable.

4. The Effect of Wet Cleaning the Kenaf on Pulp Yield and Quality and Mill Operation

In the commercial pulping of nonwood plant fibers, such as bagasse and straw, it has been found very advantageous to wet clean the fibrous raw material ahead of the digester. As shown by the studies of the USDA, similar advantages would accrue to kenaf processing in the pulping system if the whole stalk or bast ribbon kenaf, either green or field dried and also after storage in any of the systems that are judged to be suitable, were wet cleaned.

In order for the kenaf, whole stalk or bast ribbon, to be in suitable form for treatment in the wet cleaning system at the pulp mill, it will have to be suitably chopped before baling or the bales must be broken down by hand or bale breakers and the kenaf then either chopped or shredded or fiberized as is done in the preparation of sugar cane stalks for the sugar mill. This step in the fibrous raw material preparation is described in greater detail in Chapter VI.

In the wet cleaning system, as described in detail in Chapter VI, the chopped or fiberized kenaf would be fed to a Hydrapulper for dispersion and washing, as is the practice with bagasse and straw before pulping. The kenaf would then be pumped through centrifugal cleaners to remove any sand before feeding it to a dewatering screen followed by a piece of equipment similar to a bagasse depither for dewatering the fibrous raw material and removing fine dirt and fiber fines and pith from it. This wet cleaning step would also remove most of the water solubles and, in the case of wet or dry bulk stored green kenaf, the lactic acid that had been formed in preserving the fiber under anaerobic conditions. Both of these, as well as the fiber fines which would be lost from the pulp later on, require extra alkali for pulping so their removal at this point in the process is a distinct advantage. In addition, this treatment of the raw fiber also puts it in a most suitable condition of moisture content for feeding it to the continuous digester with the screw feeder.

Admittedly, it would be possible to omit the wet cleaning step for the kenaf by merely fiberizing it and wetting it sufficiently to handle it in the screw feeder to the continuous digester or by feeding small portions of broken bales of kenaf from storage directly into a batch digester. This would not really increase the yield of pulp desirable for papermaking because it would result in the dirt and fiber fines and pith being lost or removed from the pulp in the processing steps beyond

the digester and where the pulp washing rate would be adversely reduced by the fines and pith. In addition, the water soluble organic materials and any acidic materials formed in storage and normally removed in the wet cleaning process would remain in the kenaf going to the digester. They would then appear in the spent liquor as dissolved solids, requiring additional evaporator and recovery furnace capacity and a larger causticizing and lime reburning system for the mill process. The heat recovered from burning the resultant additional spent liquor organic solids, which would go into the process if the kenaf were not wet cleaned, would have little, if any, net value as steam to the mill. This is because the additional power load to process the extra spent liquor and the low pressure steam required to evaporate it are about equal to the high pressure steam which is produced and the power it will generate when the extra spent liquor is burned in the recovery boiler.

It is realized that there will be an increased load on the stream pollution control facilities of the mill resulting from the wet cleaning process for the fiber unless the effluent from this department can be used for irrigation without treatment. However, it is judged that this step in fiber preparation is necessary and will also put the kenaf in the best condition to be pulped in a continuous horizontal tube-type digester. This will also produce pulps of higher initial freeness values than for pulps for which the kenaf fiber was not wet cleaned and will enhance the physical strength properties and cleanliness of the bleached pulp. This will allow the use of pulp washing equipment of smaller size than is the case when kenaf is not wet cleaned. This also results in the lowest production cost for chemicals and utilities used without any appreciable loss in pulp yield actually suitable for sale as market pulp for papermaking.

Therefore, the fiber wet cleaning process as described, or some suitable modification, considered as being standard for the modern nonwood plant fiber pulp mills should be used for the Mekong project mill because it will maintain pulp production at lowest cost and assure the highest quality required for the market by removing fines and non-fibrous debris that the customer would prefer not to have in the pulp. Any slight loss in yield resulting from the wet cleaning process is more than compensated for by improved mill operation and runnability of the pulp through the pulp mill and the papermaking operation.

5. Pulping and Bleaching Processes and Conditions Suitable
for the Manufacture of Paper Pulp from Kenaf in the
Mekong Project Mill

In the literature surveyed, it has been found that practically every possible grade of kenaf paper pulp, from high yield mechanical pulp to fully bleached chemical pulp, has been produced experimentally in laboratories by the standard processes used in industry. All the possibilities for making these grades of pulp in the Mekong model mill have been reviewed in Section 6.1. of Chapter I of this Study.

As is the case with making the major grades of market paper pulp and paper and paperboard from wood and nonwood plant fibers commercially, the Consultants have chosen the products that could be made in a one line pulp mill from both whole stalk and ribbon kenaf that would be most suitable for the market in and future needs of the Mekong Basin countries. For the manufacture of these products, a project mill process design had to be chosen that would have the best chance for economic and technical viability and could also produce the highest quality of product suitable for world export markets when necessary.

Once the choice was made of a project mill to produce full chemical unbleached and bleached paper pulps, it was possible to eliminate such full chemical pulping procedures as the neutral and the alkaline sulfite processes, the acid bisulfite process, and the oxygen-alkali process for the reasons given in Chapter I, Section 6.1. This decision left the standard soda and sulfate processes for consideration for pulping kenaf in the Mekong project mill. This is because the other processes have too many complicating factors in bleaching or spent liquor recovery. Also, the product paper pulp quality would not in most cases be as high as that achieved with either of the two processes chosen and as used on nonwood plant fibers in commercial operations all over the world.

In the technical investigations on kenaf pulping that have been reviewed in Chapter I, Section 2.6., of this Study, and as is well known in the commercial pulping of other nonwood plant fibers, there is some indication that whole stalk kenaf pulped to the same Kappa number by the sulfate (or kraft) process would have slightly higher yield and strength properties as compared to soda pulp due to the woody nature of the core material which apparently does not pulp quite as well by the soda process. In the case of the bast ribbon, there do not appear to be any appreciable physical and chemical differences between the pulps made by either process. The marketability of the pulps can be expected to be the same for either process.

In the operation of the pulp mill, the chemical process can be expected to vary from full soda to full sulfate, depending upon the makeup chemical used based on the comparable purchased costs, on a sodium content basis, of salt cake (sodium sulfate), soda ash (sodium carbonate), and caustic soda (sodium hydroxide). In addition, there will be a certain amount of excess caustic soda available for make-up from the generating from salt (sodium chloride) of chlorine and caustic soda for the bleach plant and this would undoubtedly be used for recovery make-up in preference to the more expensive chemicals purchased outside. During possibly short periods of production of unbleached pulps, when the bleach plant and integrated chemical generating plant would not be operating and caustic soda produced at the mill would not be available, then the cheapest form of sodium chemical would be purchased and used for make-up.

With this explanation of the chemical make-up variation expected, the Consultants will refer to the Mekong project mill as being based on the soda process and model pulping conditions will be chosen on that basis. These parameters would serve just as well for the sulfate process.

In reviewing the kenaf pulping investigations, it has been noted that the standard modern commercial procedure for cooking nonwood plant fibers in a horizontal, tube-type continuous digester has been used only once for a pilot plant test on whole stalk kenaf as described by Clark, Cunningham, and Wolff (63) of the U.S. Dept. of Agriculture. It is very unfortunate that only this limited amount of information on the continuous pulping of kenaf whole stalk is available and there is none for the bast ribbon. This situation has resulted because very few pulping laboratories in the world have a pilot plant continuous digester, whereas most of them have batch digester facilities. It is interesting to note that the short cooking time in which complete pulping of kenaf whole stalk would be achieved in a continuous digester has also been indicated by the finding reported by Guttry (21) and Uhr (29, 30). They reported on a full-scale mill pulping trial in large stationary digesters, where it was indicated that whole stalk kenaf can be pulped satisfactorily in a time of 30 minutes to and 15 to 20 minutes on pressure which is a third to one half the time required for pulping wood in commercial practice and for kenaf whole stalk and bast ribbon in batch digesters in the laboratory studies and other mill trials reviewed in this Study.

It should be pointed out that one of the most successful bamboo pulp and paper mills in India, Seshasayee Paper and Board, Ltd., uses the horizontal tube continuous digester for pulping bamboo and, of course, most of the large straw and bagasse mills do also, as it is the most suitable digester for the bulky fibrous raw materials.

This information corroborates the long term judgement of the Consultants that either form of kenaf, ribbon or whole stalk, should be pulped in a continuous digester of the horizontal tube-type, the same as is the case for other nonwood plant fibers.

However, it is believed that data from the batch digester cooks, where the kenaf samples have been properly stored and wet cleaned before pulping, can be used for making estimates of the continuous cooking conditions and chemical requirements that would be used in the Mekong project mill for the two types of kenaf pulps - whole stalk or bast ribbon - as shown in Table VII.1.

In reviewing the data in the literature on the bleaching of either kenaf whole stalk or bast ribbon soda or sulfate pulps, nothing could be found indicating that the modern conventional sequences of continuous bleaching either wood or nonwood fiber plant full chemical pulps would not be perfectly satisfactory. It is judged that on the basis of data reported on laboratory or pilot plant batch bleaching tests, the most basic suitable bleaching sequence for either form of kenaf for the Mekong project model mill to produce market pulp of 85 percent brightness with maximum preservation of papermaking strength properties would be chlorination, caustic extraction, calcium hypochlorite, and chlorine dioxide (the CEHD sequence) followed by a final wash with sulfur dioxide as an anti-chlor agent. This is not to say, however, that future experience in continuous bleaching systems with kenaf pulps may not show other sequences or that slight modifications of this sequence might have some advantages from the standpoint of cost, reducing the pollution load, and preserving the optimum chemical and physical strength properties of the finished bleached pulp product.

Therefore, the bleaching sequence CEHD has been chosen for the project mill and treatment conditions with the estimated bleaching chemicals consumption shown in Table VII.1. will be used as the basis for estimating the pulp bleaching cost and purchased chemical requirements for the Mekong project model mill which will be capable of producing both whole stalk and bast ribbon kenaf bleached paper pulp for market.

Estimated Average Pulping and Bleaching Chemical Requirements
and Conditions for Field Dried and Wet Cleaned Kenaf

	Whole Stalk	Ribbon	Retention Time (Hr.)	Temp. (°C)	Cons. (%)
<u>Cooking Conditions</u>					
Active alkali (% Na ₂ O)	18	15			
Steam pressure (atm. gage)	8.9	8.9			
Temperature (°C)	180	180			
Dwell time in digester (min.)	20	12			
Kappa (no.)	26	18			
<u>Bleaching Chemicals Used</u> (Based on ADMT Bleached Pulp)					
Chlorination stage (% Cl ₂)	5	3.5	0.75	25	3.5
Caustic extraction stage (% NaOH)	2	1.5	1.5	65	12
Calcium hypochlorite stage (% Cl ₂)	2	1.0	2.5	40	12
Chlorine dioxide stage (% ClO ₂)	0.5	0.5	4	75	12
Sulfur for SO ₂ anti-chlor (% S)	0.2	0.2	-	-	-

Note: Final brightness 85% TAPPI.

Table VII.1.

In estimating these pulping and bleaching chemical requirements and choosing these conditions, it is emphasized that the ribbon, consisting of mostly bast fibers throughout, will cook uniformly and can be cooked to preserve the fiber's optimum bleached pulp strength properties at an economical balance for pulping vs. bleaching chemicals. In the case of the whole stalk, with its two dissimilar fibrous components, the kenaf has to be cooked so that there will be a reasonable balance between the cost of cooking chemicals as compared to the cost of bleaching chemicals with consideration given to trying to preserve optimum pulp quality from the mixed fibers. This will result in overcooking and overbleaching the bast fiber fraction and undercooking and underbleaching the woody core fibers in the whole stalk in comparison with the case where the two components would be pulped and bleached separately for optimum results for each of the two types of fibers. However, most of the scientists studying the use of kenaf for paper pulp recognize that, from the practical standpoint and in the light of present technology for preparing kenaf fiber for pulping, the pulping and bleaching of whole stalk kenaf without separating the components can be considered a reasonable compromise for producing this type of pulp with medium physical strength properties, comparable to hardwood sulfate and softwood sulfite pulps.

6. The Anticipated Characteristics of Kenaf Pulps in Washing and Screening

In practically all of the research reports reviewed for this Study in the Sub-Sections of Section 2.6. of Chapter I, mention has been made of the slow drainage characteristics, as expressed by the low initial freeness values, of both types of the kenaf pulps in comparison to the corresponding long fibered and short fibered wood pulps. This has been the case particularly for the kenaf whole stalk pulp because its woody core material, when pulped separately, yields pulp that without beating has all the characteristics, particularly the high bonding strength as shown by tensile and bursting strength, and the low tearing strength and the slow drainage condition of a pulp which has undergone drastic refining. Further refining of this woody core fraction of the pulp takes place merely on pumping the stock around. Also, the accumulation of the pulp fines in the circulating liquor and white water throughout the entire mill process has a very undesirable effect in the processing and on the resultant pulp properties for many grades of papers.

This characteristic of slow drainage for the kenaf pulps, when they include all the fibrous fines, pith, and parenchyma cells originally in the raw fiber, is their greatest drawback when compared to wood pulps. It is only in comparison with a very slow draining pulp, such as from rice straw that has not been thoroughly wet cleaned or bagasse that has not been well depithed, that the kenaf whole stalk pulps that have been produced in the few mill scale runs reported showed any superior characteristic in relation to the drainage of the water from the pulp. Although prolonged proper wet storage under anaerobic conditions and wet cleaning both have a beneficial effect on the draining of water from the pulp by removing part of the fraction of the kenaf pulps mostly responsible for this adverse drainage characteristic, the accompanying loss of short fibers, particularly in the case of the kenaf whole stalk pulps by fractionation would be considerable. It has been reported that this is not the case for the kenaf bast ribbon pulps and some early investigations reviewed indicated that kenaf pulp produced from retted bast fiber had very high initial freeness values and was very difficult to refine in the laboratory beater. Therefore, the characteristics for drainage and resistance to beating to a reasonable degree for paper strength development can, in the case of kenaf bast ribbon pulp, be improved by wet cleaning the fibrous raw material before the digester. As stated before, this is the most advantageous point for removing the deleterious components of kenaf pulps from the standpoint of improving the subsequent operations further on in the processing.

Therefore, in designing the washing equipment for the brown stock and in the bleach plant for the Mekong project mill, particularly for operation on whole stalk kenaf, these factors of slow drainage, the related sensitivity of the pulp to hydrate further on pumping, and the effect of the accumulation of fines in the circulating liquor and white water systems will have to be given full consideration. The paper mills which use the kenaf pulps, particularly the whole stalk pulp, will also have to recognize these factors and adjust their equipment and processing steps accordingly.

It is interesting to note again, as previously mentioned in the review sections of Section 2.6. in Chapter I of this Study, that the studies at the CSIRO in Australia have placed great emphasis on the practical operating difficulties that would result from the slow drainage characteristics of the kenaf pulps and are working on means to reduce this problem to a practical level.

This slow drainage of kenaf whole stalk pulp was observed during the full scale mill runs at Eastern Paper Mills Corp. in Sri Lanka but the results there were an improvement over the much lower pulp washing rate per area of washer face that is normally achieved on rice straw pulp in the same mill. In the same runs, considerable foaming on the brown stock washers was observed for kenaf soda pulp but this is not expected to be an insurmountable problem for kenaf pulp in view of the success with which the highly foaming, resinous softwood pulps are washed on vacuum washers.

The kenaf bast ribbon pulp, after the fibrous raw material has been properly wet cleaned at the pulp mill, can be expected to have a more favorable drainage characteristic than whole stalk pulp will have. It should compare favorably with wood pulps in this characteristic for washing rates. The design of the washers in the pulp mill and the bleach plant for the whole stalk pulp can, therefore, be expected to give them a greater washing capacity for ribbon pulp than for the whole stalk pulp tonnage of 200 ADMT/day for which the project mill is designed.

The information reported on commercial screening of kenaf pulp is very limited. All of the laboratory work appears to have been done with flat screens with slots which are not recommended for nonwood plant fibers for modern operations. In the information on screening kenaf whole stalk pulp at the Eastern Paper Mill in Sri Lanka, it was reported that the centrifugal type screens with 1.2 mm. diameter holes that were used on straw pulp rejected all the long fiber portion of the pulp. However, by increasing the perforations in the screen plate

to 2.0 mm. diameter, the rejection of the bast portion of the fiber was satisfactorily eliminated. This fractionation of whole stalk kenaf pulp by screening might be desirable for manufacturing certain grades of paperboard, for example linerboard, where the long fiber fraction would be very desirable as the secondary layer on top of the sheet to reduce the possibility of score cracking of the outer liner in scoring corrugated boxes made therefrom. However, for making bleached market pulp, it is anticipated there will be no problems in screening and centrifugally cleaning the pulp. In fact, it may be that, for customers requiring pulp of higher freeness than can be produced with whole stalk kenaf by wet cleaning it ahead of the digester, a suitable grade could be produced by removing a low percentage of the pulp as fines in the screening operation with screen plates having much smaller diameter perforations than the ones used for straw pulp.

When the problems that have been reported and are to be expected in the washing and screening operations in the manufacture of the kenaf pulps are considered in proper perspective, it does not appear that they would place any constraints on the Mekong project mill operation or impart qualities to the pulps which would inhibit their marketability.

7. Pulp Drying and Papermaking with Kenaf Pulps

Up to the present, there have been no published data on extended commercial runs of specific market grades of dried pulp or of paper either 100 percent bast ribbon or whole stalk kenaf pulp produced from properly wet-cleaned raw fiber using the optimum continuous pulping and bleaching processes that are used successfully for other nonwood plant fibers.

The trial runs on paper machines for which data have been reported have been reviewed in Section 2.6. of Chapter I of this Study. With one exception, they have been made on a semi-commercial or pilot plant scale using kenaf whole stalk pulp produced in batch digesters and usually with batch stages of bleaching. In most cases, the bleaching sequences used were those which do not produce the relatively high brightness pulps required to match those sold on the world market, and imported into some of the Mekong Basin countries, without losing bleached pulp yield and severely damaging the physical strength properties of the pulp.

Further than this, the picture of the behavior and handling of the kenaf pulp, particularly the whole stalk pulp, on the pulp dryer and paper machine has been complicated and clouded by the fact that the kenaf pulps were usually mixed with other pulps in the fibrous furnish. This has, of course, proved that various grades of paper, generally the printing and writing grades, can be made successfully from kenaf whole stalk chemical pulp as a part of the fibrous furnish together with other pulps being used. However, this does not show clearly the commercial qualities of paper that would be obtained and the problems that would result with 100 percent furnishes of kenaf pulps in comparison with the wood pulps which are used to make the major grades of unbleached and bleached papers used in the world.

For example, the only run of kenaf whole stalk pulp reported as having been made over a pulp dryer was the one at Hudson Pulp and Paper Company which is reviewed in Sub-Section 2.6.4.9. of Chapter I of this Study. There it was found that, because the foaming and slow drainage characteristic of the pulp on the cylinder former prevented formation of a thick pulp sheet that would transfer over the long draws in the press section, it was impossible to run a 100 percent kenaf whole stalk pulp through the dryer. The addition of 40 to 60 percent pine sulfate pulp was required in order to process the pulp over the wet end and through the dryer.

The Consultants must point out that such an adverse report on the handling of kenaf pulp during this test in Florida has been given serious consideration in choosing the pulp dryer for the Mekong Basin project mill. The equipment considered as the most suitable for kenaf whole stalk pulp would consist of a fourdrinier wet end followed by a press section designed with an adequate conveying system for the web of pulp between presses. In order to minimize the loss in production time resulting from breaks in the dryer section, a can dryer of the paper machine type with any necessary dryer fabrics would be used. Such a machine, designed to handle the kenaf whole stalk pulp with its unusually low drainage characteristic, would be perfectly adequate for kenaf bast ribbon pulp and could also be converted, at a later date, for the manufacture of various grades of paper from either type of kenaf pulp.

From the results obtained at Eastern Paper Mills Ltd. in Sri Lanka on running grades of paper from kenaf whole stalk pulp in a mixed furnish with rice straw pulp, it appears that the kenaf whole stalk pulp would have better drying characteristics than would normally be expected in view of its slow drainage attribute. At Hudson, it was found that kenaf whole stalk pulp added to pine sulfate pulp improved the drying rate of the web of paper, presumably because the slow drainage of the kenaf pulp in the furnish necessitated reducing the refining of the pine stock fraction in the mixture in order to maintain the same drainage rate of the mixed furnish on the wire.

The Consultants do not anticipate any operational problems in making the full range of the major paper grades from kenaf bast ribbon sulfate or soda pulp. However, in the case of the kenaf whole stalk full chemical pulps, consideration will have to be given to its slow drainage characteristic, the high content of fines as compared to wood pulps, and the fact that only a very little pumping and refining of the stock produces a further undesirable lowering of the water drainage from the pulp in processing.

On the other hand, the Consultants also recognize that for some grades of paper, particularly those requiring that the pulp be well hydrated by refining or beating for the development of certain characteristics, such as smoothness, low porosity, etc., the slow drainage of kenaf whole stalk pulp may not be disadvantageous for the final product. The characteristic of high tensile (or bursting) strength already developed without any appreciable refining would allow the use of kenaf whole stalk pulp in mixed fiber furnishes with a long fibered pulp fraction with high tearing strength that would then require little or no prior separate refining to obtain the desired

test properties for the finished paper. In essence, it might well be said that including whole stalk kenaf chemical pulp in a mixed furnish might substantially replace beating and refining of the other pulp portion of the furnish for many paper grades. If this is the case in general, then it will turn out that, what has been considered by many researchers to be a disadvantage for kenaf whole stalk pulp, would be a good selling point for this product of the Mekong Basin pulp mill.

Although these factors have not been definitely established by past investigations, it would appear that they will easily be developed further as soon as sufficient quantities of an optimum quality kenaf whole stalk chemical pulp can be produced for extended trials as a replacement for hardwood sulfate and softwood sulfite pulps in the various paper mills in Thailand.

There is then a final inherent benefit in the design of the pulp dryer in the Mekong Basin project mill so that it can be converted, in the future, to the manufacture of the grades of paper for which kenaf whole stalk chemical pulp would be best suited as 100 percent of the fibrous furnish.

8. Environmental Control for the Kenaf Paper Pulp Mill

8.1. Introduction

In Section 6.3.2. of Chapter I, it was pointed out that a kenaf paper pulp mill in the Mekong Basin area would best be located at a site in proximity to a river with appreciable flow throughout the year for disposal of treated liquid effluent from the mill. It was on this basis, together with other equally favorable and available items of infrastructure and the kenaf raw material supply, that the Consultants picked one of the two primary mill sites for location of the proposed mill on the Nam Mun River below Ubon Ratchathani in Northeast Thailand.

The possibility is recognized by the Consultants that, within a few years, it will be required by pollution control authorities that wood pulp mills in developed countries sewer very little, if any, effluent to a receiving stream, even after treatment. Processes now being developed for waste water treatment and reuse in the mill will eventually result in a closed water cycle for a paper pulp mill. However, it is expected that these closed water systems for pulp mills will have high capital and operating costs, resulting in increased prices for pulp that those countries would export to the world market.

In developing the technical parameters and costs for the present project for the Mekong Basin kenaf pulp mill, it has been assumed that the mill will be designed for air and stream pollution control capabilities to match those of a modern pulp mill in the developed countries at the present time. The tried and proven systems in use and planned for this project would minimize air and stream pollution at the suggested sites and should not result in adverse relations with the general public living in the neighborhood or down stream on the Nam Mun River.

8.2. Stream Pollution Control Facilities for the Mekong Basin Paper Pulp Mill

The mill effluents, after treatment in the systems and by the processes considered for this Study, would meet the standards which have been developed and are required by the Ministry of Industry in Thailand for pulp and paper mills. These standards as shown in Table VII.2., are reasonable and adequate for the foreseeable future for a pulp mill located on a stream with flow as great as the Nam Mun River.

Starting with the design of the pulp mill itself, there would be maximum practical recycling of waste waters and condensates that would not require internal treatment for reuse. All fiber-bearing waste effluents from the pulp processing that could not be reused would be collected in a common sump and pumped to a circular clarifier with mechanical sludge removal equipment. This primary treatment would remove a large proportion of the settleable solids such as the fiber fines and dirt. These solids would be further dewatered by settling in ponds or by the use of centrifuges or vacuum filters and used for land fill.

The effluent from the primary clarifier would then be combined with the non-fiber bearing waste effluent from the mill and the mixture would be neutralized as required. Following this, required recycled secondary sludge and chemical nutrients to aid biological digestion in the following secondary treatment system would be added.

The secondary treatment system is designed to remove or destroy the soluble organic materials in the effluent which would consume oxygen in the receiving stream if not eliminated and would result in the destruction of fish life and unpleasant odors in the river downstream of the pulp mill during seasons of low rainfall. This reaction of organic materials in effluent with the oxygen in the receiving stream is defined and measured as the Biochemical Oxygen Demand (BOD). The secondary treatment system for pulp mill waste effluent at the project mill would be designed to remove 80 to 90 percent of the BOD, thereby enabling the mill to meet the final effluent standards set by the pollution control authority.

Table VII.2.

Thailand Working Standards for Industrial
Effluent Discharging to Inland Streams

Item	Allowable for Pulp and Paper Industry
BOD (5 days 20° C.)	20 ppm. max. (60 ppm. max. at high dilution factor)
Suspended Solids	
Dilution Ratio 8 to 150	30 ppm. max.
150 to 300	60 ppm. max.
300 to 500	150 ppm. max.
Dissolved Solids	2,000 ppm. max.
pH	5 to 9
Permanganate Value	60 ppm. max.
Sulfide (as H ₂ S)	1 ppm. max.
Cyanide (as HCN)	0.2 ppm. max.
Oils, Grease, & Tar	None
Formaldehyde	1 ppm. max.
Phenols & Cresols	1 ppm. max.
Free Chlorine	1 ppm. max.
Insecticides	None
Radioactive Materials	None
Zinc, Chromium, Arsenic, Silver, Selenium, Mercury, Lead, Nickel (Individually or in Total)	1 ppm. max.
Temperature	40° C. max.
No Disagreeable Taste and Odor	

It should be kept in mind that part of the waste effluent from the mill that is responsible for the BOD results from the small amount of residual spent liquor and liquor leaked that is not recycled to the spent liquor recovery system. The rest of the BOD in the effluent from the mill comes from the pulp fines which do not settle out in the primary clarifier and the lignin and other carbohydrate material solubilized and removed from the pulp in the bleaching process.

There are several types of secondary treatment systems for BOD removal that could be used for the Mekong project mill and they are all widely used by pulp and paper mills in developed countries to achieve a high degree of pollution control.

Where land area adjacent to the pulp mill is limited, the activated sludge system is used because of the short retention time required to treat the effluent. This system usually requires ammonium hydroxide and phosphoric acid to improve the microbiological activity of recycled sludge added to the effluent before it passes through an aeration basin followed by secondary clarifiers.

Where sufficient land is available and there are residents in the area adjacent to the effluent treatment plant, mechanically aerated lagoons are used for the secondary treatment system as this effectively reduces the possibility of odors from the lagoons.

In the case of the Mekong project mill located at some of the possible sites selected, the secondary treatment system could consist of a large stabilization basin or oxidation lagoon in which the effluent would be impounded for about 40 days so that natural aeration and decomposition of the organic materials causing BOD would result. The use of a large impounding basin with variable level control would make it possible to retain much of the effluent in the lagoon during periods of low flow in the river. Then, during periods of high rainfall and large river flow, the stored effluent could be released to the receiving waters and diluted as allowed by the Government's standards.

There is one effluent problem relating to nonwood plant fiber pulp mills, such as those that would process bagasse or kenaf, that would not be present at a wood-based pulp mill. This is the extra burden on water pollution control facilities that would result from the pith and fines and soluble organic materials that would be removed in wet cleaning the fiber. Calculations by the Consultants have shown that, in the case of a pulp mill that is wet depithing bagasse and thereby removing about 12 percent of the remaining soluble sugars and

carbohydrates and pith from the previously moist depithed bagasse, the BOD load in the untreated effluent leaving the pulp mill increases to about four times and the suspended solids increase to about twice the losses from a similar size of wood pulp mill. When it is considered that wet cleaning the field dried kenaf, either ribbon or whole stalk, would remove about 20 percent of the total dry solids content of the fibrous raw material in the waste effluent from this section of the pulp mill, it becomes a possibility that the untreated waste effluent from a kenaf fiber wet cleaning preparation system would contain 6 to 8 times the load of BOD and 3 to 4 times the amount of suspended solids in the untreated waste effluent as compared to a wood pulp mill of the same productive capacity.

There are several procedures to be considered for avoiding or eliminating the heavy load that the wet cleaning system would put on the waste effluent treating plant of a kenaf pulp mill.

By not using any sort of a wet cleaning system and leaving the water soluble materials and pith and fines with the kenaf fed into the digester, much of these undesirable items would not appear in the untreated waste effluent from the mill but would show up in the spent liquor to the recovery system and as additional fines lost in the bleach plant washer effluents and white water from the pulp dryer. This would require a much larger recovery system for the spent liquor and any steam and power generated from the additional organic material retained as spent liquor would be required to evaporate, burn, and recausticize the liquor. Thus, there would be no net gain of heat values to the mill. In addition, the detrimental slow drainage characteristic of kenaf whole stalk pulp would be made even worse in comparison to pulp for which the raw fiber had been properly wet cleaned. This would require larger washing and bleaching drums in the pulp mill and would result in a slower draining pulp that would not be as acceptable on the market as a freer pulp.

Wet cleaning the kenaf fiber with dilute black liquor rather than water and then sending the spent liquor to the recovery system would create practically the same problems in the recovery system as not cleaning at all. However, this would at least result in getting some of the pith cells and fines out of the stock before washing and bleaching, just as in the case of wet cleaning with water.

Another procedure for reducing the load of soluble organic materials in the untreated waste effluent from the wet cleaning system of the mill would be to store all the kenaf in wet bulk form for several months until all sugars were converted to lactic acid and the BOD reduced. This would be only a partial solution to the problem as there would still remain the matter of the pith and fines in the untreated effluent from the wet cleaning system with the cost of their removal an appreciable factor in the cost of operating the mill.

Considering these important factors among kenaf fiber preparation, pulping, recovery of spent pulping liquor, and waste effluent treatment as discussed, it appears that the lowest cost and most practical solution to these interrelated problems would be to use the untreated waste effluent from the kenaf fiber wet cleaning system as irrigation water for crops that tolerate it. This system has been used in the case of at least one bagasse pulp mill. This waste water would not contain any of the chemical wastes from the pulp mill. It would return to the soil and crops under irrigation the trace minerals, nutrients, and organic material washed out of the kenaf fiber. The present plan for the Mekong Basin project mill incorporates this method of disposal for that part of the untreated waste effluent originating in the kenaf raw fiber wet cleaning system.

8.3. Air Pollution Control Facilities for the Mekong Basin Paper Pulp Mill

Although it is not expected that the Mekong project pulp mill would be located in a densely populated urban area, where traces of air pollution in the form of odor and dust together with harmless and odorless water vapor appearing as plumes of steam for a short distance from the mill stacks and vents might possibly result in public criticism, it is planned that a high degree of air pollution control will be achieved in normal operation of the pulp mill.

The standard equipment used for air control that would be installed would be chosen taking into consideration the fact that this project mill will operate somewhere in the recovered chemical balance between a full chemical soda pulp mill and a full chemical sulfate pulp mill, depending upon the soda losses in operation and the price of purchased salt cake (sodium sulfate which is the makeup chemical for a sulfate mill) on a sodium basis relative to the price of other makeup chemicals, caustic soda (sodium hydroxide) or soda ash (sodium carbonate), that would be available.

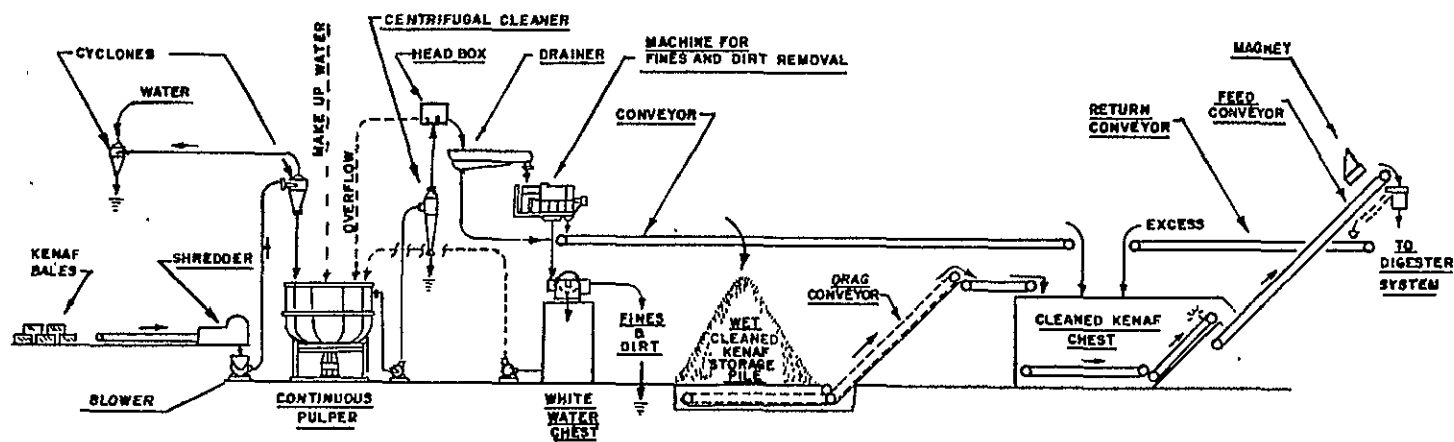
Adequate air pollution control would be achieved for this project by use of the following equipment and processes properly sized for the designed production tonnage rate of the mill:

- (a) A weak black liquor oxidation system for the spent liquor ahead of the multiple effect evaporators. This unit is required only because of the possibility of operating the plant as a sulfate mill.
- (b) Noncondensable gases from the digester blow and the multiple effect evaporators would be burned in the lime kiln or recovery furnace.
- (c) The recovery furnace would be sized for designed normal load operation so that odorous hydrogen sulfide would not be released from the furnace, as happens under overload conditions with insufficient combustion air, when operating as a sulfate pulp mill. The recovery furnace stack gases would be passed through a cascade evaporator for final direct evaporation of the black liquor from the multiple effect evaporators before the liquor is burned in the recovery furnace. The cascade evaporator is chosen for this service because it is the most suitable final evaporator for the higher viscosity black liquor resulting from pulping nonwood plant fibers than from pulping wood. The stack gases are finally

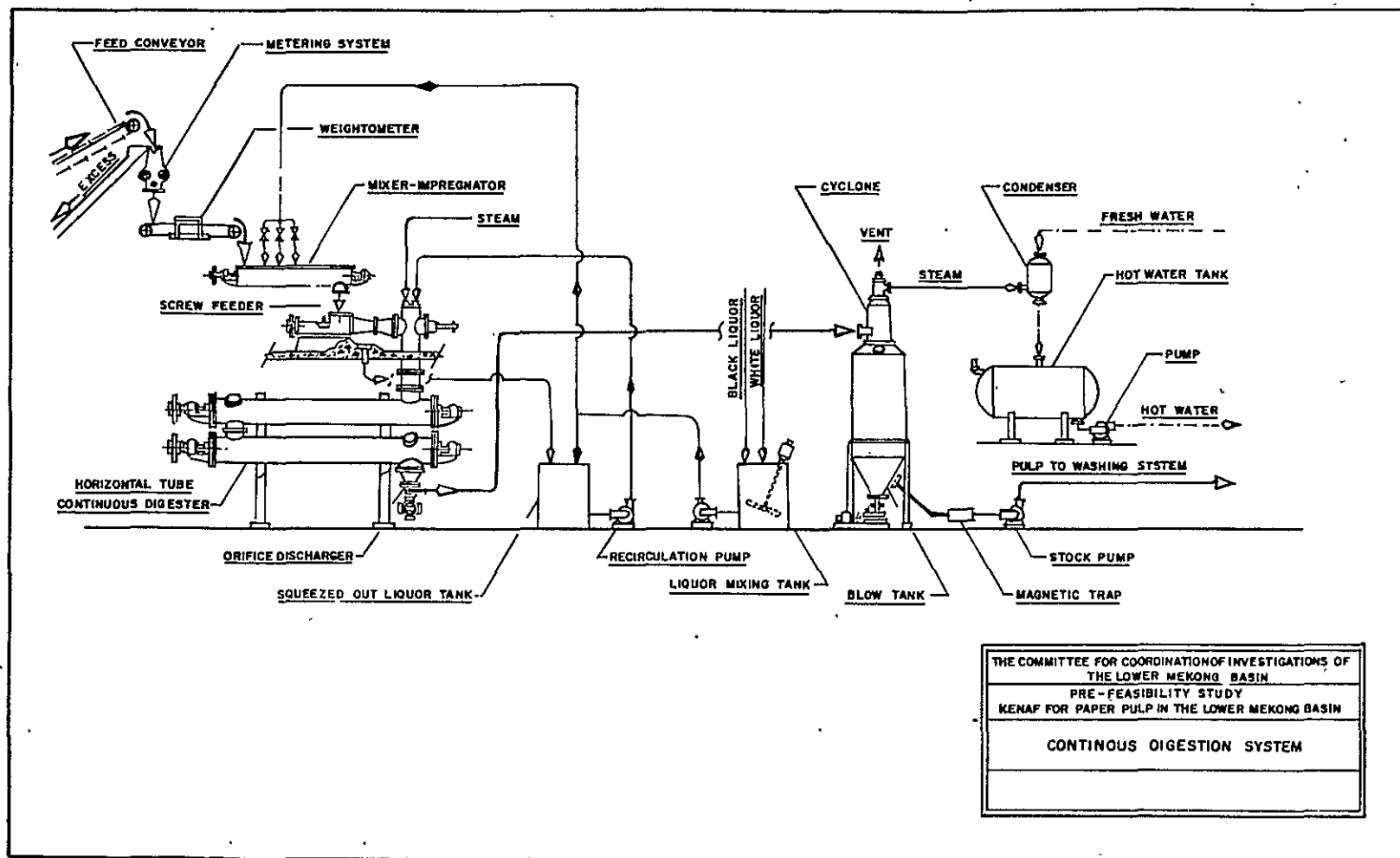
cleaned of entrained sodium salt fume in an electrostatic precipitator operating at about 98 percent efficiency. Fume from the dissolving tank on the recovery furnace would be reclaimed with a suitable scrubber.

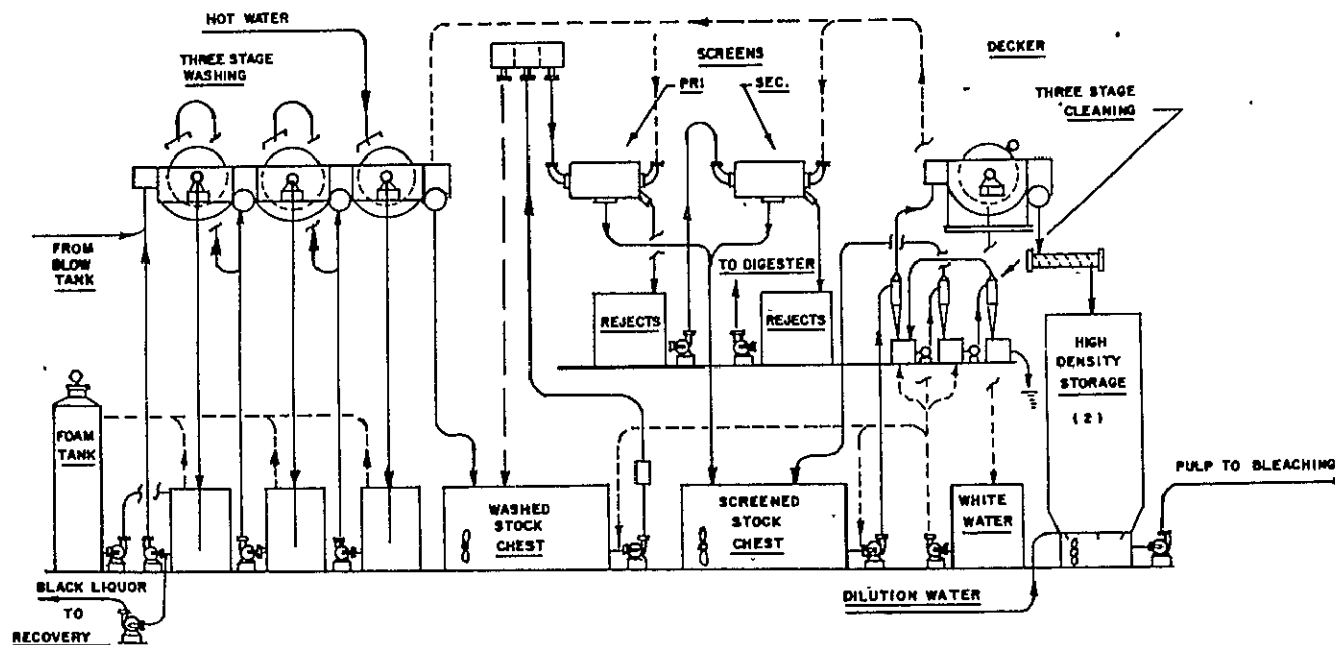
- (d) The lime kiln would be equipped with a high efficiency Venturi-Scrubber to minimize this normally troublesome source of dust. All returned lime handling equipment would be designed to minimize any dust from this source in the causticizing system.
- (e) Any traces of gases from the bleaching chemicals would be absorbed in water for disposal to the waste effluent treating system.

Operation of the mill at normal designed capacities with these items of equipment, including these facilities for air pollution control, would prevent any undue nuisance from the mill and criticism from the neighboring residents and pollution control authorities.



THE COMMITTEE FOR COORDINATION OF INVESTIGATIONS OF THE LOWER MEKONG BASIN
PRE-FEASIBILITY STUDY KENAF FOR PAPER PULP IN THE LOWER MEKONG BASIN
PREPARATION AND WET CLEANING OF KENAF



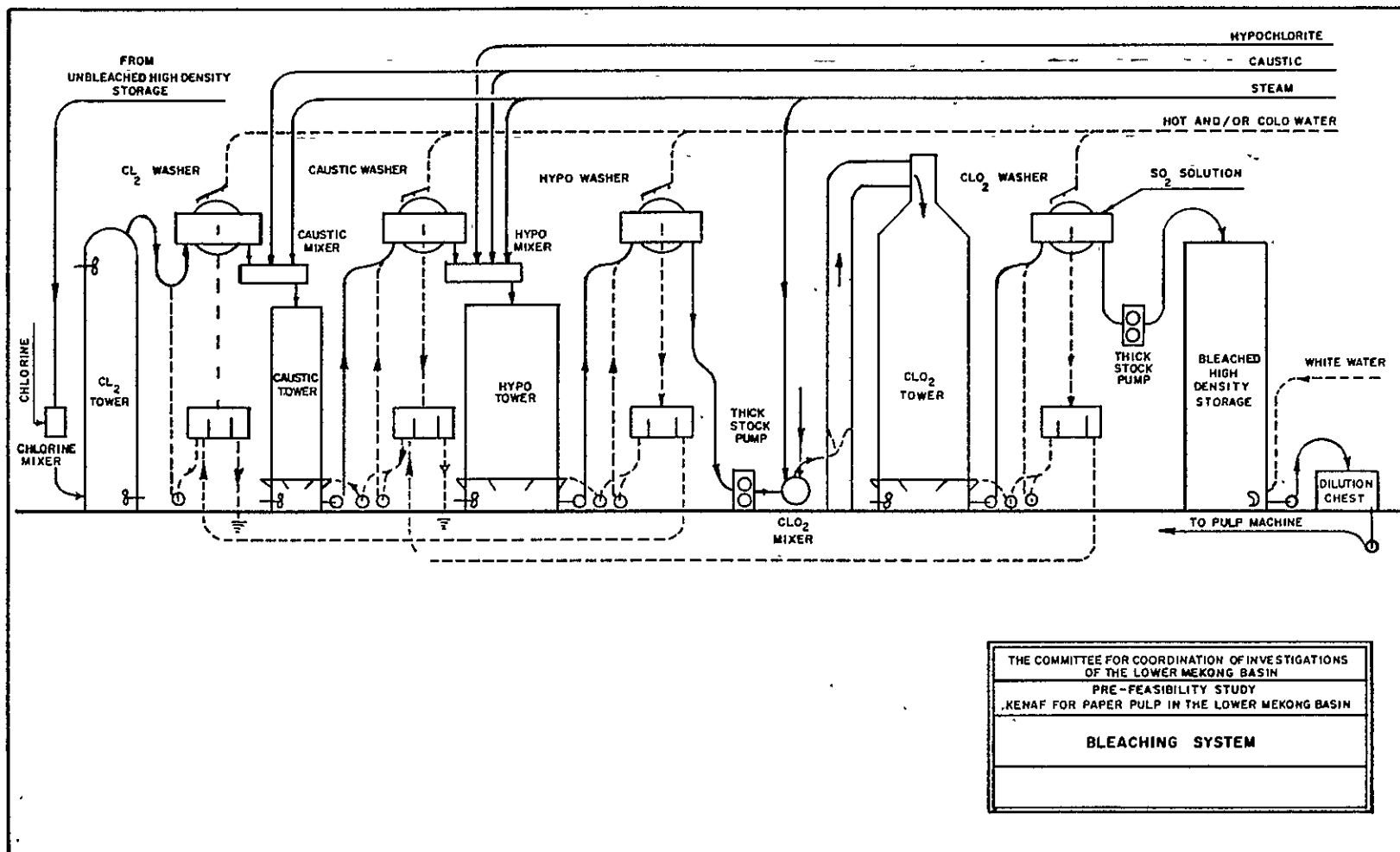


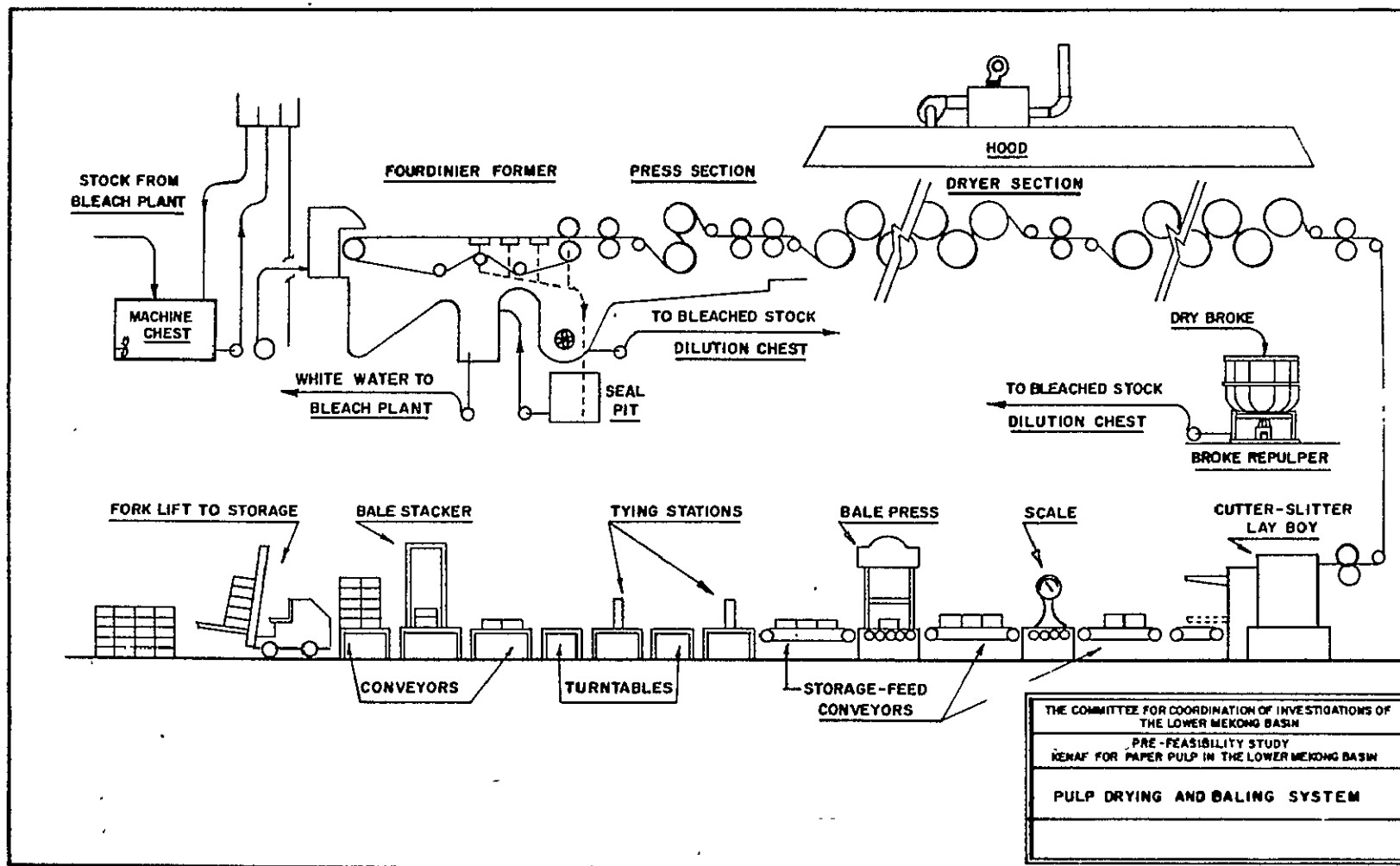
THE COMMITTEE FOR COORDINATION OF INVESTIGATIONS OF
THE LOWER MEKONG BASIN

PRE-FEASIBILITY STUDY
KENAF FOR PAPER PULP IN THE LOWER MEKONG BASIN

WASHING AND SCREENING SYSTEM

Fig. VII.3.





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FIG. VII.5.

CHAPTER VIII - FINANCIAL ASPECTS OF KENAF PRODUCTION FOR PAPER PULP MANUFACTURE

1. Farm Revenue from Kenaf Textile Fiber Production in Northeast Thailand

In view of the dominant position of Northeast Thailand as present and future kenaf producer in the Mekong Basin area, kenaf production economics in that region will be used as a basis for projecting raw material costs to the kenaf pulp industry.

Since any pulp mill using Northeast Thailand H. sabdariffa as raw material will have to purchase the kenaf from the same growers who normally produce retted kenaf fiber for use by the local mills and for export, the revenues the farmers realize from the sale of their retted kenaf must be examined in order to be able to establish a suitable price to be offered for kenaf produced for paper pulp, a price which will also provide an adequate incentive to the growers to produce such kenaf for the pulp mill and guarantee an acceptable income to the farmers.

It is very difficult to obtain reliable data on the prices actually paid to the Northeast Thailand kenaf growers at the farm level, as these are subject to a number of factors and influences including:

- Quality:

Normally, the kenaf grower in the Northeast does not grade his fiber prior to its sale but sells it as "Mixed Grade". However, the buyer differentiates between "regular" and "good" ungraded kenaf. More recently, an attempt has been made to induce the growers to grade their fiber into "A", "B" and "C" quality before sale - particularly in the Nakorn Ratchasima and Chaiyaphoom Pioneer Kenaf Development Project areas - but this practice is not yet widespread. Fiber quality is influenced not only by growing conditions and the diligence of the farmer, but also by the availability of retting water which varies from location to location and season to season.

- Demand:

This changes from year to year, season to season, and month to month, as well as often from location to location, and is determined most frequently by international jute market conditions over which the Thai kenaf industry has no control.

- Local Conditions:

Prices received by the individual farmer may not reflect the general level due to his indebtedness to the buyer and his lack of access to a larger market and thus his dependence upon the goodwill of the local merchant.

Table VIII.1. lists the farm level prices for "Mixed Grade" retted kenaf fiber for the 1970 to 1974 period as recorded by the Division of Agricultural Economics of the Ministry of Agriculture. It will be seen that, from 1972 onwards, the Division records prices for "A", "B" and "C" grade rather than for "regular" and "good" ungraded fiber as previously. For purposes of the present Study, a column showing average "Mixed Grade" prices, both per month and per calendar year, has been added to the data. Furthermore, since the trade and such international agencies as the FAO consider the jute and kenaf season to run from July 1 to June 30, separate annual price averages have been calculated on such seasonal basis.

Fig. VIII.1. shows the data recorded in Table VIII.1. graphically. Table VIII.1. and Fig. VIII.1. are commented upon as follows.

The "averages" shown for the years 1972, 1973 and 1974 do not represent the actual "Mixed Grade" price received by the growers, since "A", "B" and "C" grade fiber are not being produced in equal proportions. Instead, it is generally accepted that the production of the various grades averages some 20 percent "A" grade, 40 percent "B" grade, and 40 percent "C" grade. Hence, since the grade distribution is weighted towards the lower grades, the actual farm level prices received by the growers must be expected to be somewhat lower than those listed in Table VIII.1. for the 1972 to 1974 period.

**Farm Level Prices for Retted Kenaf in Northeast Thailand
1970 to 1974**

Unit = Baht/Kilogram

Month	1970			1971			1972				1973				1974				1970 to 1974 Average
	Regular	Good	Average	Regular	Good	Average	"A"	"B"	"C"	Average	"A"	"B"	"C"	Average	"A"	"B"	"C"	Average	
January	1.94	1.99	1.97	2.06	2.36	2.21	3.09	2.47	2.12	2.56	3.41	2.98	2.62	3.00	2.17	1.85	1.54	1.85	2.32
February	1.87	1.89	1.88	1.99	2.34	2.17	2.87	2.68	2.45	2.67	3.59	3.26	2.76	3.20	1.99	1.85	1.69	1.84	2.35
March	1.63	1.66	1.65	2.06	2.37	2.22	2.92	2.64	2.28	2.61	3.57	3.28	2.63	3.16	1.88	1.54	1.52	1.65	2.26
April	1.56	1.64	1.60	2.32	2.67	2.50	3.46	2.94	2.52	2.97	3.11	2.66	2.54	2.77	2.15	1.72	1.27	1.71	2.31
May	1.60	1.70	1.65	2.49	2.78	2.64	3.12	2.55	2.46	2.71	3.53	3.07	2.50	3.03	2.12	1.74	1.38	1.75	2.36
June	1.60	1.68	1.64	2.42	2.73	2.58	3.67	3.55	2.83	3.35	3.48	2.68	1.92	2.69	2.08	1.81	1.39	1.76	2.40
July	1.63	1.74	1.69	2.40	2.64	2.52	4.81	4.00	3.75	4.19	3.05	2.87	2.43	2.78	2.21	1.73	1.29	1.74	2.58
August	1.80	1.89	1.85	2.40	2.65	2.53	3.82	3.47	2.77	3.35	2.69	2.39	1.92	2.33	2.54	2.07	1.51	2.04	2.42
September	1.91	1.98	1.95	2.24	2.37	2.31	3.28	2.89	2.50	2.89	2.73	2.02	1.65	2.13	2.93	2.43	1.92	2.43	2.34
October	2.05	2.07	2.06	2.29	2.44	2.37	2.88	2.64	2.22	2.58	2.27	2.09	1.56	1.97	3.19	2.72	2.23	2.71	2.34
November	2.07	2.18	2.13	2.53	2.66	2.60	2.84	2.78	2.47	2.70	2.23	2.06	1.30	1.86	3.33	2.95	2.27	2.85	2.43
December	2.16	2.24	2.20	2.59	2.73	2.66	3.01	2.60	2.27	2.63	2.08	1.88	1.12	1.69	3.10	2.68	2.22	2.67	2.37
Average	1.82	1.89	<u>1.86</u>	2.32	2.56	<u>2.44</u>	3.31	2.93	2.55	<u>2.93</u>	2.90	2.60	2.08	<u>2.53</u>	2.39	2.09	1.69	<u>2.06</u>	<u>2.37</u>
Average "Mixed Grade" Price per Season - July 1 to June 30			1970/1971			1971/1972			1972/1973			1973/1974							
			2.18			2.66			3.02			1.94							

Source: Division of Agricultural Economics

Note: Baht 20.00 = US\$1.00

Table VIII.1.

FARM LEVEL PRICES FOR RETTED KENAF IN NORTHEAST THAILAND 1970 TO 1974

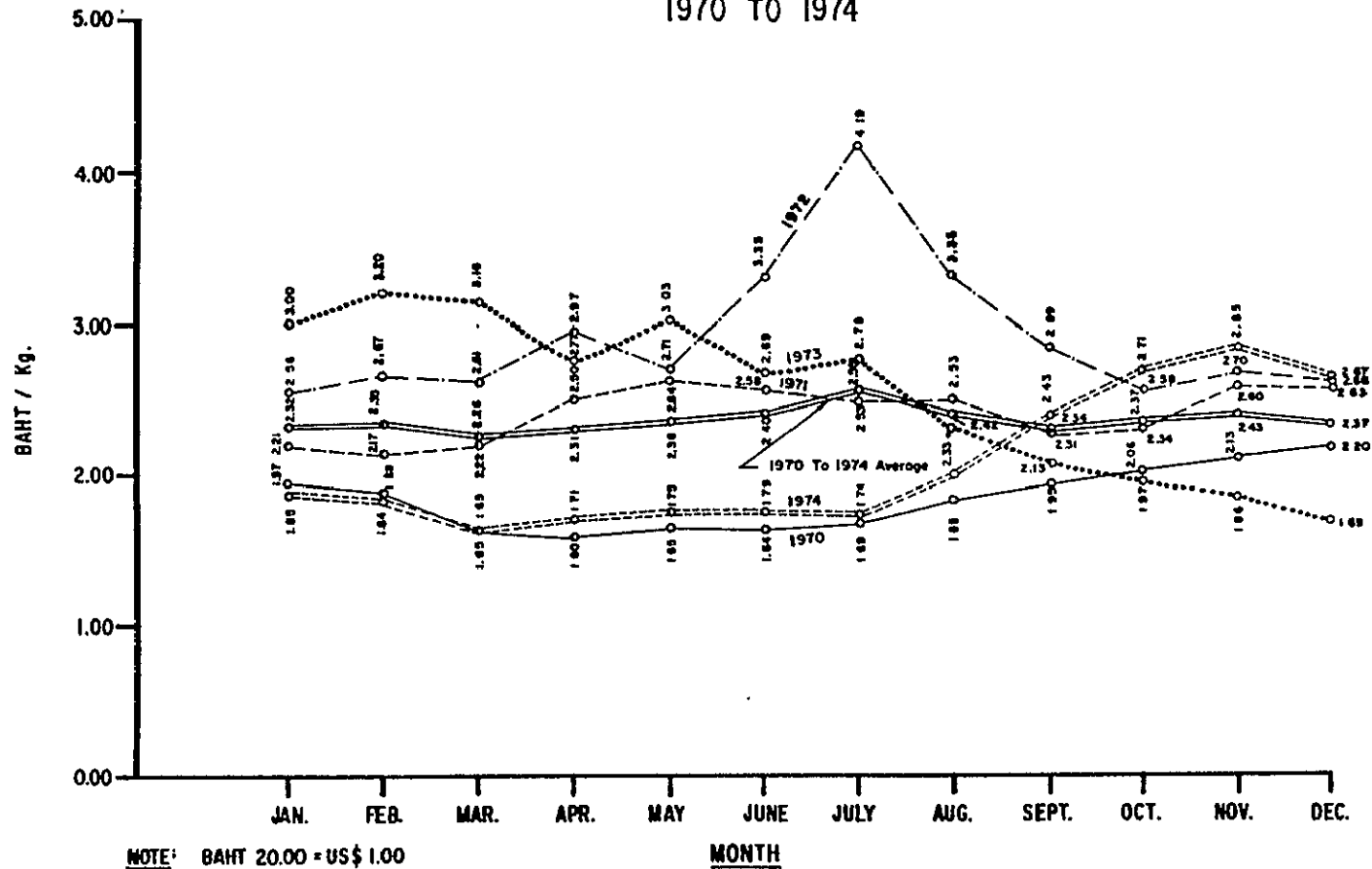


FIG. VIII.1.

Incidentally, the encouragement of the farmers to pregrade their fiber and the establishment of a price incentive for the higher grades are recent actions and highly to be recommended, since they should lead to the production of a greater percentage of high grade kenaf - of advantage both to the local bag mills and the Thai kenaf export trade - as well as to higher farm income. Nevertheless, differences of opinion still exist as to the adequacy of available retting facilities to substantially increase high grade fiber production (there is a Government sponsored program to improve and expand retting facilities), the adequacy of the price spread between "A" grade and "B" grade fiber (฿0.30 to 0.40 averages in Table VIII.1.) to provide a sufficient incentive to the grower to invest the additional effort and care required for the production of a higher grade (which, as a result of its greater cleanliness, will weigh somewhat less than a lower grade), the methods and efficiency of required farmer education programs, and similar considerations.

Table VIII.1. and Fig. VIII.1. show that, although there is an appreciable differential between year-to-year farm level prices, average month-to-month variations over the 5-year period shown are very small indeed (see the "1970 to 1974 Average" curve in Fig. VIII.1.). Hence, although the farm level prices do fluctuate during any one year and that sometimes substantially (฿3.00/kg. in January 1973, ฿1.69 kg. in December 1973), there are no consistent low or high price level periods which recur each year. This is important with regard to the pulp mill's raw material purchasing policies.

It was considered of interest to attempt to provide a check against the farm level price information listed in Table VIII.1. and Fig. VIII. 1. The Thai Jute Association (TJA) estimates that, on the average, the prevailing price for "A" grade fiber in Bangkok (ex godown, export baled) minus ฿1.50/kg. represents the then prevailing "Mixed Grade" price at the farm level. Table VIII.2. was prepared on the basis of the relevant price information from Thai Jute Association and FAO records where the farm level prices ("A" grade Bangkok price minus ฿1.50) are shown in brackets. The data so obtained are presented graphically in Fig. VIII.2. It will be noted that the information is tabulated on a "seasonal" (July to June) rather than on a "calendar year" (January to December) basis.

Bangkok and Farm Level Kenaf Prices
1969/1970 to 1974/1975

Unit = Baht/Kilogram

Month	1969/1970	1970/1971	1971/1972	1972/1973	1973/1974	1974/1975	Average 1969/1974
	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	
	(1) (2)	(1) (2)	(1) (2)	(1) (2)	(1) (2)	(1) (2)	(1) (2)
July	2.75 (1.25)	2.91 (1.41)	3.93 (2.43)	5.85 (4.35)	3.54 (2.04)	3.64 (2.14)	3.77 (2.27)
August	2.68 (1.18)	2.75 (1.25)	3.62 (2.12)	5.85 (4.35)	3.40 (1.90)	4.02 (2.52)	3.72 (2.22)
September	2.68 (1.18)	2.85 (1.35)	3.47 (1.97)	5.05 (3.55)	3.28 (1.78)	4.10 (2.60)	3.57 (2.07)
October	2.31 (0.81)	3.07 (1.57)	3.53 (2.03)	3.85 (2.35)	3.15 (1.65)	4.30 (2.80)	3.36 (1.86)
November	2.59 (1.09)	3.30 (1.80)	3.69 (2.19)	3.90 (2.40)	3.15 (1.65)	4.30 (2.80)	3.48 (1.98)
December	2.75 (1.25)	3.30 (1.80)	4.36 (2.86)	4.25 (2.75)	3.11 (1.61)	4.10 (2.60)	3.65 (2.15)
	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>	
January	3.00 (1.50)	3.30 (1.80)	4.14 (2.64)	4.55 (3.05)	3.27 (1.77)	3.90 (2.40)	3.69 (2.19)
February	3.11 (1.61)	3.05 (1.55)	4.35 (2.85)	4.51 (3.01)	3.14 (1.64)	3.80 (2.80)	3.66 (2.16)
March	2.91 (1.41)	3.05 (1.55)	4.84 (3.34)	4.31 (2.81)	3.08 (1.58)	3.70 (2.20)	3.64 (2.14)
April	2.83 (1.33)	3.94 (2.44)	5.56 (4.06)	4.19 (2.69)	3.18 (1.68)	3.75 (2.25)	3.94 (2.44)
May	2.90 (1.40)	3.95 (2.45)	5.85 (4.35)	- -	3.30 (1.80)	3.85 (2.35)	4.00 (2.50)
June	3.13 (1.63)	3.95 (2.45)	5.85 (4.35)	3.83 (2.33)	3.44 (1.94)	4.00 (2.50)	4.04 (2.54)
Seasonal Average	2.80 (1.30)	3.29 (1.79)	4.43 (2.93)	4.56 (3.06)	3.25 (1.75)	3.96 (2.46)	3.71 (2.21)

Notes: (1) Grade "A", Ex Godown, Bangkok Price
(2) Grade "A", Ex Godown, Bangkok Price Less \$1.50 = "Mixed Grade" Farm Level Price
Baht 20.00 = US\$1.00

Sources: Thai Jute Association
Intergovernmental Committee on Jute, Kenaf and Allied Fibers, FAO, Rome

Table VIII.2.

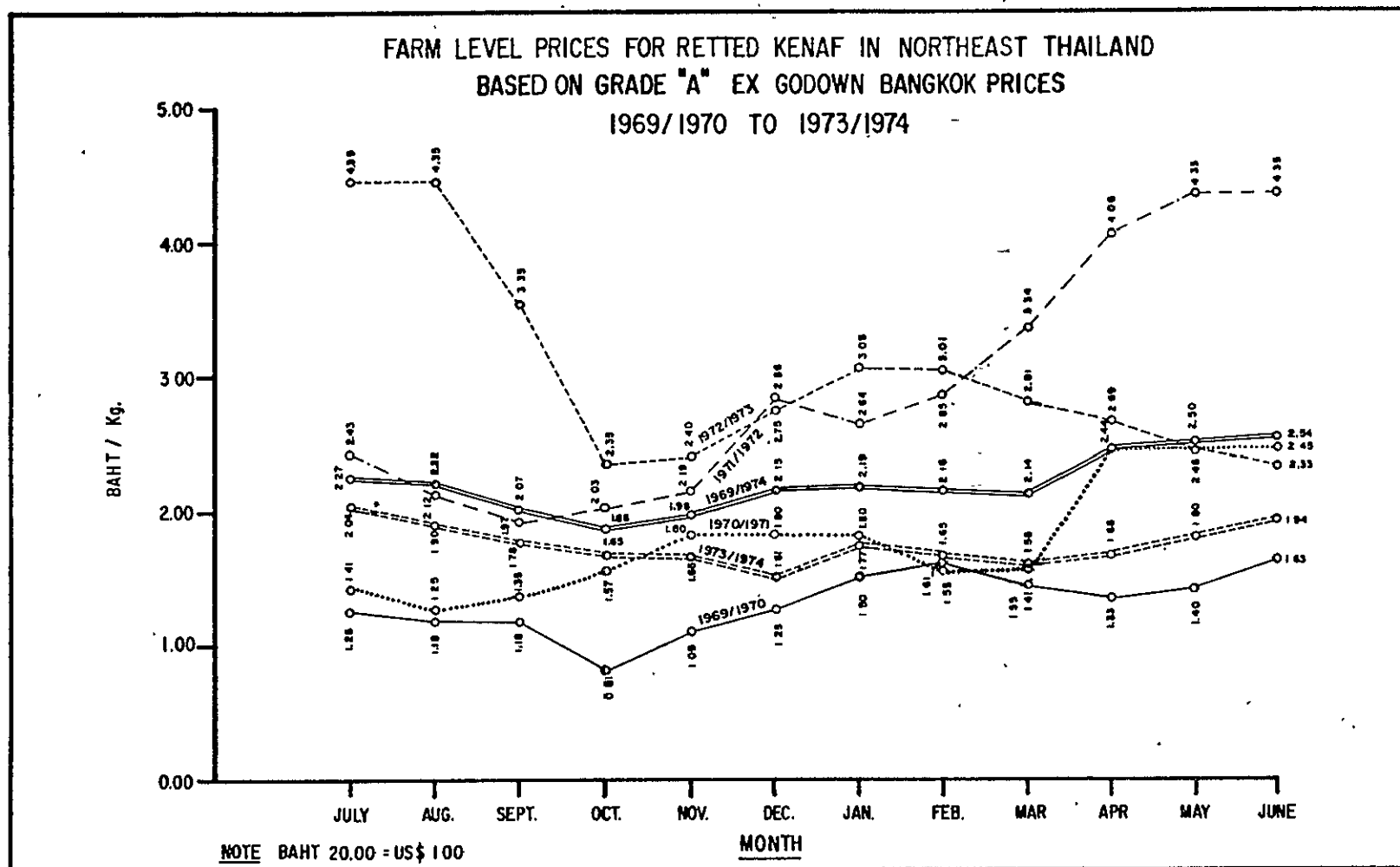


Fig. VIII.2.

The annual average price data for the four most recent seasons recorded in Table VIII.1. (Source: Division of Agricultural Economics) and Table VIII.2. (Source: TJA/FAO) differ somewhat as follows:

	<u>Table VIII.1.</u>	<u>Table VIII. 2.</u>
1970/1971	฿2.18/kg.	฿1.79/kg.
1971/1972	฿2.66/kg.	฿2.93/kg.
1972/1973	฿3.02/kg.	฿3.06/kg.
1973/1974	฿1.94/Kg.	฿1.75/kg.

The latter table indicates greater price fluctuations from season-to-season - and from month-to-month - than the former and appears to depict actual upcountry price levels somewhat more accurately, particularly since it better reflects the larger percentages of "B" and "C" grade in "Mixed Grade" fiber whereas the "Average" column in Table VIII.1. assumes equal proportions of "A", "B" and "C" grade.

Similarly, average month-to-month farm level prices over the 1970/1971 to 1973/1974 period show a somewhat greater although still not very significant variation, namely ฿0.32/kg. in Table VIII.1. and ฿0.68/kg. in Table VIII.2., and Fig. VIII.2. shows a more pronounced seasonal price trend, with a low in October/November (when new crop retted kenaf becomes plentifully available) and a high between April and August (when only speculatively hoarded old crop fiber is available).

Overall farm level prices for the entire 1970/1971 to 1973/1974 period average ฿2.37/kg. according to Table VIII.1. and Fig. VIII.1. and ฿2.21/kg. for the 1969/1970 to 1974/1975 period according to Table VIII.2. and Fig. VIII.2. By combining all of the data, an overall average farm level price of ฿2.30/kg. (US\$0.115/kg.) is calculated and this also appears to be a reasonable figure based on field and commercial experience.

In an attempt to reverse the 1974/1975 decline in kenaf production, the Thai bag and hessian mills decided, in April 1975, to offer the growers guaranteed minimum prices for kenaf as follows:

Grade "A" - P3.50/kg.
Grade "B" - P3.20/kg.
Grade "C" - (P2.50/kg.) (no guaranteed price established;
assumed at this level based upon
normal price differentials in the
past).

The above prices were understood for unbaled fiber delivered jute mill. Assuming an average grade distribution of 20 percent Grade "A", 40 percent Grade "B", and 40 percent Grade "C", the average "Mixed Grade" price, per ton, delivered mill, would then be as follows:

200kg.	at	P3.50	=	P 700.00
400kg.	at	P3.20	=	P1,280.00
400kg.	at	P2.50	=	<u>P1,000.00</u>
				P2,980.00/ton
	say	=		P 3.00/kg.

Since the average farmer is not able to deliver his fiber to the mill himself (most of the mills are located outside of the principal kenaf production areas) and, in any case, not without transportation costs, a minimum amount of P0.25/kg. should be deducted from the above price and the average farm level price would then be P2.75/kg. (US\$0.138/kg.).

In July 1975, the mills announced a further minimum price increase to P4.00/kg. for "A" grade, bringing the average farm level price, calculated in the same manner as above, to P3.25/kg. (US\$0.1625/kg.).

Table VIII.3. lists the gross farm revenues at various retted fiber prices for "Mixed Grade" at the farm level and on the assumption of a Northeast-wide average retted fiber yield of 184 kg./rai (1,150 kg./ha.) (see Table II.13.). It will be seen that the mills' two 1975 price support actions have increased the kenaf growers' potential gross farm revenues quite substantially as follows:

Table VIII.3.

Farm Revenues at Varying Retted
Kenaf Fiber Prices

Farm Level Price		Farm Revenue ⁽¹⁾	
Baht/Kg.	US\$/Kg.	Baht/Rai	US\$/Ha.
1.50	0.075	276.00	86.25
1.75	0.088	322.00	101.20
2.00	0.100	368.00	115.00
2.25	0.113	414.00	129.95
2.30	0.115	423.20	132.25
2.50	0.125	460.00	143.75
2.75	0.138	506.00	158.70
3.00	0.150	552.00	172.50
3.25	0.163	598.00	187.45
3.50	0.175	644.00	201.25
3.75	0.188	690.00	216.20
4.00	0.200	736.00	230.00

Note: (1) Average Retted Kenaf Fiber Yield = 184 kg./rai
= 1,150 kg./ha.

	<u>Farm Level Price</u>		<u>Farm Revenue</u>	
	<u>Baht/Kg.</u>	<u>US\$/Kg.</u>	<u>Baht/Rai</u>	<u>US\$/Ha.</u>
1969/1970 to 1974/1975				
Average	2.30	0.115	423.20	132.25
Minimum Price, April 1975	2.75	0.138	506.00	158.70
Minimum Price, July 1975	3.25	0.163	598.00	187.45

Since the kenaf exporters will have to compete with the mills to secure their supplies, the projected farm revenue increase by $\text{฿}174.80/\text{rai}$ (US\$55.20/ha.) can be expected to apply to the entire kenaf crop.

2. Estimated Farm Prices of Kenaf Pulping Raw Materials

2.1. South Asian Kenaf

2.1.1. Whole Kenaf Stalks

The farm-price estimates in this sub-section will be considered to apply to both whole stalk and chopped whole stalk raw material. By "whole stalks" are understood stalks which have been topped, i.e. from which the topmost 20 to 30 cm. soft under-developed portion has been cut off, and from which the remaining leaves and seed capsules have been stripped. The additional labor involved in cutting these stalks into, say, 3 in. (7.5 cm.) pieces is minor and assumed not to be chargeable by the peasant farmer.

The investment in land, equipment, farm inputs and labor up to the stage of harvesting and shocking the kenaf stalks for field drying is identical for whole stalk (for paper pulp) and retted fiber (for textile purposes) production. However, whereas the farmer would be able to sell his field dry stalks to the pulp mill without further processing, except for topping and chopping, he still has to invest a considerable amount of time, effort and labor into retted fiber production, including: the transport of his stalks to the retting water, which may be close by but may also be as far as 30 to 40 km. from his field under Northeast Thailand conditions; the loading of the stalks into the retting ditch, pond, tank or river, and their submersion; the stripping and washing of the retted fiber; and fiber drying and baling. Statistics show that from 40 to 45 percent of overall costs and labor are invested in the conversion of field dry stalks into baled retted fiber, all of which the farmer can save himself by selling his field dry stalks to the pulp mill. For purposes of this Study and in order to provide an attractive incentive to the growers, it is nevertheless assumed that the project would provide the same gross revenue per rai (or hectare) to the farmer for whole or whole chopped stalks as for retted fiber, although it seems reasonable to anticipate that he would be satisfied with a substantially lower income in view of the cost and labor savings which would allow him either to expand his kenaf planting area, plant another crop, or increase his leisure time.

Table VIII.4. then shows the prices per ton of field dry stalks payable at varying retted kenaf fiber prices and varying field dry stalk yields, where a farm level "Mixed Grade" retted fiber price of $\text{P}3.25/\text{kg}$. ($\text{\$}0.1625/\text{kg}$.) (see Section VIII.1. above) and a field dry stalk yield of $1,200 \text{ kg./rai}$ ($7,500 \text{ kg./ha.}$) (see Chapter V, Section 3.2.1.) or a field dry stalk price of $\text{P}498$ ($\text{US}\$24.90$) per metric ton, delivered local collection center, will be used as a basis of calculation in this Study.

Table VIII.4. clearly demonstrates the great influence of the field dry stalk yield per unit area on the price per ton of raw material to the pulp mill since, under Northeast peasant farmer production conditions, all investment costs, except stalk transportation, remain constant at all yield levels. Whereas this Study assumes that a field dry stalk yield of $1,200 \text{ kg./rai}$ ($7,500 \text{ kg./ha.}$) can reasonably be anticipated as a Northeast average, Table V.5. shows that, with row-planting and reasonable attention to variety selection alone, yields of $1,500$ to $2,000 \text{ kg./rai}$ ($9,375$ to $12,500 \text{ kg./ha.}$) and more can be achieved without difficulty and certainly with the help of a limited research and extension program such as the project might well be able to implement, where the cost of such development work would be far more than offset by the savings in raw material costs. (At an annual requirement of $206,000$ tons of field dry stalks, the savings resulting from a stalk yield increase from $1,200 \text{ kg./rai}$ ($7,500 \text{ kg./ha.}$) to $1,500 \text{ kg./rai}$ ($9,375 \text{ kg./ha.}$) would amount to $\text{P}498 - \text{P}399 = \text{P}99 \times 206,000 = \text{P}20,400,000$ or $\text{US}\$1,020,000$ per year).

Fig. VIII.3. shows graphically the relationship between the field dry kenaf stalk prices payable at various retted kenaf fiber prices and the stalk yield per unit area and again emphasizes the economic importance of bringing stalk yields up to at least the $1,500 \text{ kg./rai}$ ($9,375 \text{ kg./ha.}$) level.

2.1.2. Kenaf Bast Ribbon

If the peasant farmer is to be induced to (a) grow kenaf for the bast ribbon pulp mill rather than another crop, and (b) to sell bast ribbon rather than whole kenaf stalks or whole chopped stalks to the mill, he must be provided with a greater price incentive than the whole kenaf stalk supplier in order to compensate him for the additional ribbon stripping work involved. It can, of course, be argued that even the production of ribbon requires substantially less work than that of retted fiber, since the farmer need not transport his stalks to the

**Field Dry Kenaf Stalk Prices Payable at Varying
Retted Kenaf Fiber Prices and Stalk Yields**

Retted Fiber Price ⁽¹⁾ Baht/Kg. (US Cents/Kg.)		1.50 (7.50)	1.75 (8.75)	2.00 (10.00)	2.25 (11.25)	2.50 (12.50)	2.75 (13.75)	3.00 (15.00)	3.25 (16.25)	3.50 (17.50)	3.75 (18.75)	4.00 (20.00)
Gross Revenue, Retted Fiber ⁽²⁾ Baht/Rai (\$/Ha.)		276.00 (86.25)	322.00 (100.65)	368.00 (115.00)	414.00 (129.40)	460.00 (143.75)	506.00 (158.15)	552.00 (172.50)	598.00 (186.90)	644.00 (201.25)	690.00 (215.65)	736.00 (230.00)
Stalk Yield Kg./Rai Kg./Ha.		-----Baht/Ton (\$/Ton) ⁽³⁾ -----										
900	5,625	307 (15.35)	358 (17.90)	409 (20.45)	460 (23.00)	511 (25.55)	562 (28.10)	613 (30.65)	664 (33.20)	716 (35.80)	767 (38.35)	818 (40.90)
1,000	6,250	278 (13.90)	322 (16.10)	368 (18.40)	414 (20.70)	460 (23.00)	506 (25.30)	552 (27.60)	598 (29.90)	644 (32.20)	690 (34.50)	736 (36.80)
1,100	6,875	251 (12.55)	293 (14.65)	335 (16.75)	376 (18.80)	418 (20.90)	460 (23.00)	502 (25.10)	544 (27.20)	585 (29.25)	627 (31.35)	669 (33.45)
1,200	7,500	230 (11.50)	268 (13.40)	307 (15.35)	345 (17.25)	383 (19.15)	422 (21.10)	460 (23.00)	498 (24.90)	537 (26.85)	575 (28.75)	613 (30.65)
1,500	9,375	184 (9.20)	215 (10.75)	245 (12.25)	276 (13.80)	307 (15.35)	337 (16.85)	368 (18.40)	399 (19.95)	429 (21.45)	460 (23.00)	491 (24.55)
2,000	12,500	138 (16.90)	161 (8.05)	184 (9.20)	207 (10.35)	230 (11.50)	253 (12.65)	276 (13.80)	299 (14.95)	322 (16.10)	345 (17.25)	368 (18.40)

Notes: (1) Mixed grade at farm level.
(2) Average retted kenaf fiber yield = 184 Kg./Rai (1,150 Kg./Ha.).
(3) Delivered Collection Center; exclusive of transportation cost to mill.

FIELD DRY KENAF STALK PRICES PAYABLE AT VARYING RETTED KENAF FIBER PRICES AND STALK YIELDS

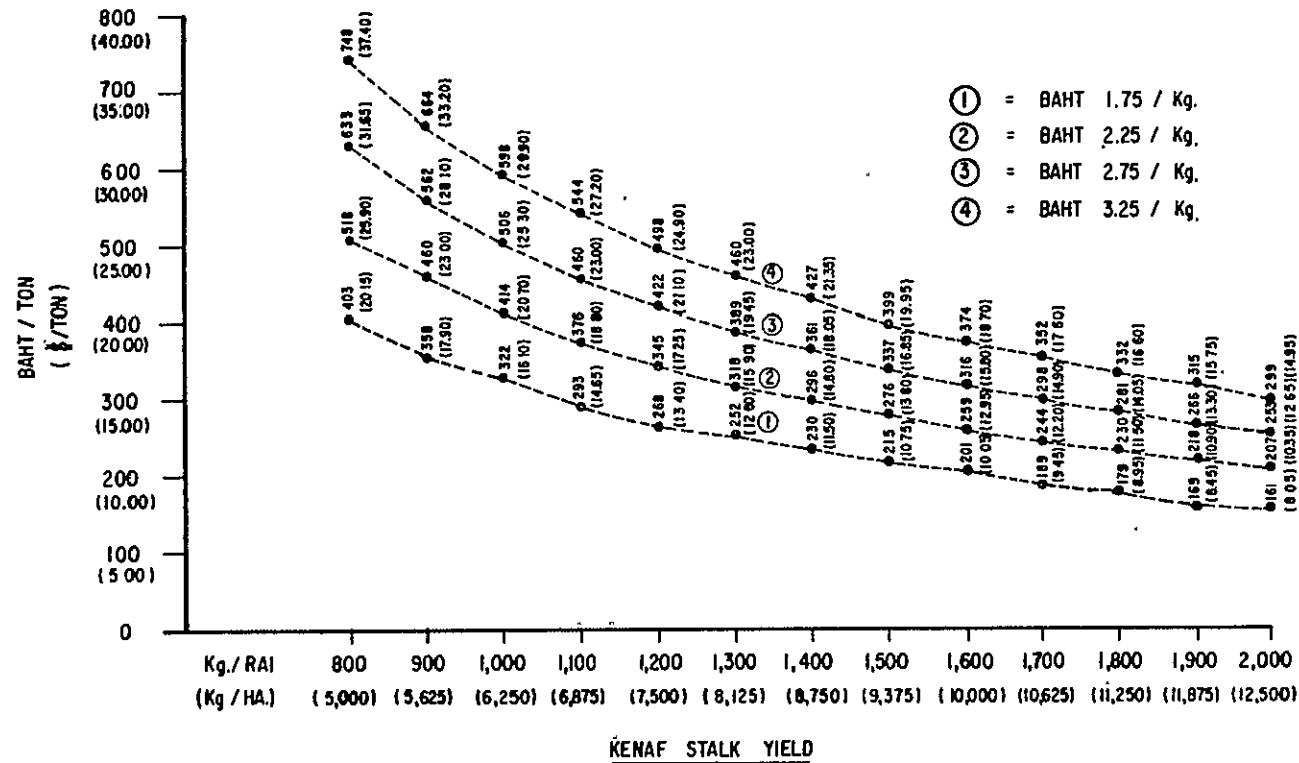


Fig. VIII.3.

retting water and load them into the retting facility and submerge them, all time consuming and/or labor intensive operations. However, since it has been assumed in the last preceding section of this Study that the grower is to be offered the same gross revenue per unit area for whole or whole chopped stalks as for retted fiber in order to provide him with an attractive incentive, an additional price allowance will have to be made to induce him to strip and sell the bast ribbon rather than the stalk material. It is felt that an increase of 10 percent in revenue would provide a more than adequate incentive towards that end. Table VIII.5. then shows the prices per ton of field dry ribbon payable at varying retted fiber prices and varying field dry ribbon yields, and Fig. VIII.4. shows this relationship graphically. Once again, the importance of increasing the yield per unit area becomes clearly apparent, particularly achievement of a minimum ribbon yield of 340 kg./rai (2,100 kg./ha.) equivalent, at 24 percent ribbon content of the whole stalk, to 1,400 kg./rai (8,750 kg./ha.) of whole stalks. A further (minor) increase to 380 kg./rai (2,400 kg./ha.) field dry ribbon yield - corresponding to a whole stalk yield of 1,600 kg./rai (10,000 kg./ha.) - would reduce ribbon raw material costs by an additional 10 percent.

In view of the fact that this Study assumes that the major source of raw material supply for the model pulp mill will be Northeast Thailand grown H. sabdariffa and based upon the foregoing discussion, a field dry ribbon price of ฿1,935 (\$96.75) per metric ton, delivered local collection center, will be used as a basis of calculation herein; this is the price shown in Table VIII.5. as payable to the grower at a ribbon yield rate of 340 kg./rai (2,100 kg./ha.) and at a "Mixed Grade" retted kenaf fiber price of ฿3.25 kg. (US\$0.1625/kg.) at the farm level.

**Field Dry Best Ribbon Prices Payable at Varying
Retted Kenaf Fiber Prices and Ribbon Yields**

Retted Fiber Price ⁽¹⁾ Baht/Kg. (US Cents/Kg.)		1.50 (7.50)	1.75 (8.75)	2.00 (10.00)	2.25 (11.25)	2.50 (12.50)	2.75 (13.75)	3.00 (15.00)	3.25 (16.25)	3.50 (17.50)	3.75 (18.75)	4.00 (20.00)
Gross Revenue, Retted Fiber ⁽²⁾ Baht/Rai (\$/Ha.)		276.00 (86.25)	322.00 (100.65)	368.00 (115.00)	414.00 (129.40)	460.00 (143.75)	506.00 (158.15)	552.00 (172.20)	598.00 (186.90)	644.00 (201.25)	690.00 (215.65)	736.00 (230.00)
Gross Revenue, Incl. 10% Ribboning Incentive Baht/Rai (\$/Ha.)		304.00 (95.00)	354.00 (110.65)	405.00 (126.50)	455.00 (142.20)	506.00 (158.10)	557.00 (174.00)	607.00 (189.70)	658.00 (205.60)	708.00 (221.25)	759.00 (237.20)	810.00 (253.10)
Ribbon Yield	 Baht/Ton (\$/Ton) ⁽³⁾										
Kg./Rai	Kg./Ha.											
290	1,800	1,048 (52.40)	1,220 (61.00)	1,397 (69.85)	1,569 (78.45)	1,745 (87.25)	1,921 (96.05)	2,093 (104.65)	2,269 (113.45)	2,441 (122.05)	2,617 (131.85)	2,793 (139.65)
340	2,100	894 (44.70)	1,041 (52.05)	1,191 (59.55)	1,338 (66.90)	1,488 (74.40)	1,638 (81.90)	1,785 (89.25)	1,935 (96.75)	2,082 (104.10)	2,232 (111.60)	2,382 (119.10)
380	2,400	800 (40.00)	932 (46.60)	1,066 (53.30)	1,197 (59.85)	1,332 (66.60)	1,466 (73.30)	1,597 (79.85)	1,732 (86.60)	1,863 (93.15)	1,997 (99.85)	2,132 (106.60)
430	2,700	707 (35.35)	823 (41.15)	942 (47.10)	1,058 (52.90)	1,177 (58.85)	1,295 (64.75)	1,412 (70.60)	1,530 (76.50)	1,647 (82.35)	1,765 (88.25)	1,884 (94.20)
480	3,000	633 (31.60)	738 (36.90)	844 (42.20)	948 (47.40)	1,054 (52.70)	1,160 (58.00)	1,263 (63.25)	1,371 (68.55)	1,475 (73.75)	1,581 (79.05)	1,688 (84.40)
530	3,300	574 (28.70)	668 (33.40)	764 (38.20)	858 (42.90)	955 (47.75)	1,051 (52.55)	1,145 (57.25)	1,242 (62.10)	1,336 (66.80)	1,432 (71.60)	1,528 (76.40)
580	3,600	524 (26.20)	610 (30.50)	698 (34.90)	784 (39.20)	872 (43.60)	960 (48.00)	1,047 (52.35)	1,134 (56.70)	1,220 (61.00)	1,309 (65.45)	1,397 (69.85)
620	3,900	490 (24.50)	571 (28.55)	653 (32.65)	734 (36.70)	816 (40.80)	897 (44.85)	979 (48.95)	1,061 (53.05)	1,142 (57.10)	1,224 (61.20)	1,306 (65.30)
670	4,200	454 (22.70)	528 (26.40)	604 (30.20)	679 (33.95)	755 (37.75)	831 (41.55)	906 (45.30)	982 (49.10)	1,057 (52.85)	1,133 (56.65)	1,209 (60.45)
720	4,500	422 (21.10)	492 (24.60)	563 (28.15)	632 (31.60)	703 (35.15)	774 (38.70)	843 (42.15)	914 (45.70)	983 (49.15)	1,054 (52.70)	1,125 (56.25)
770	4,800	395 (19.75)	460 (23.00)	526 (26.30)	591 (29.55)	657 (32.85)	723 (36.15)	788 (39.40)	855 (42.75)	920 (46.00)	986 (49.30)	1,052 (52.60)

Notes: (1) "Mixed Grade" at Farm Level.
(2) Average Kenaf Fiber Yield = 184 Kg./Rai (1,150 Kg./Ha.)
(3) Delivered Collection Center.

Table VII.5.

FIELD DRY BAST RIBBON PRICES PAYABLE AT VARYING RETTED KENAF FIBER PRICES AND RIBBON YIELDS

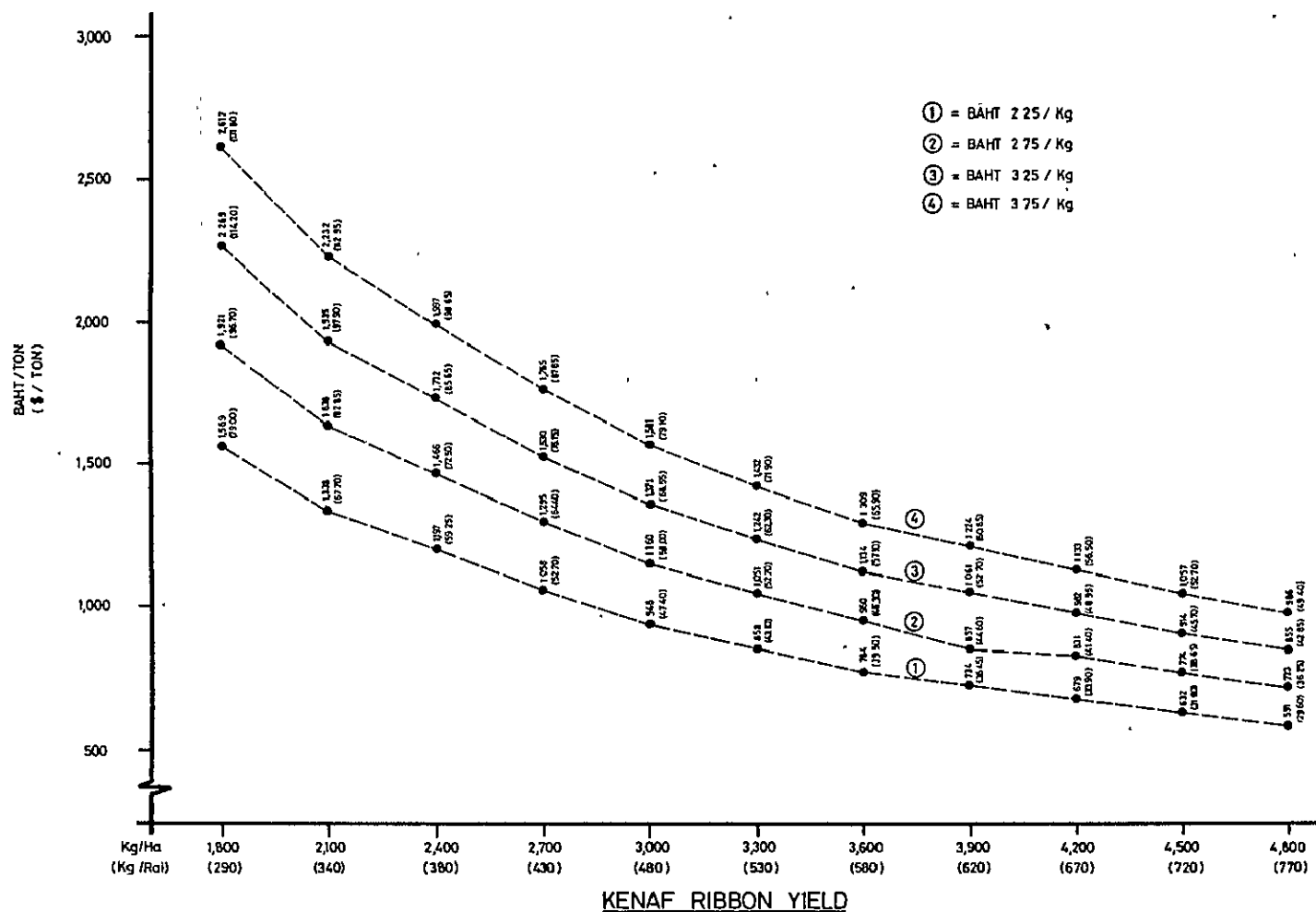


Fig. VIII.4.

2.2. Western Hemisphere Kenaf

In principle, the pulp mill should expect to pay the same raw material price to the peasant farmers for H. cannabinus as it does for H. sabdariffa, since the pulp yields and qualities are expected to be the same for both species. However, on the one hand, H. cannabinus is expected to outyield the local species by a ratio of 2:1 but, on the other hand, its production will require, apart from better soil, increased outlays on at least such inputs as seed and fertilizer. Hence, the question of economic returns and production incentives for the Western Hemisphere kenaf producer in the Basin area must be examined and compared with those of the South Asian kenaf grower in the same area.

The additional input costs for H. cannabinus vis-a-vis H. sabdariffa are estimated as follows:

Land Preparation:

Since H. cannabinus should be grown on somewhat heavier soils than the predominantly sandy soils generally used for H. sabdariffa (at least in Northeast Thailand), deeper plowing and harrowing will be required. However, as the small holder does not cost his or his family's labor nor the amortization of his draft animals or agricultural implements, no monetary value is placed on the additional land preparation work; instead, it is considered to be offset by part of the labor savings on weeding and thinning.

Seed:

Seed requirements have been indicated at 2 kg./rai (12.5 kg./ha.) for H. sabdariffa and 4 kg./rai (25 kg./ha.) for H. cannabinus (Section V.2.3.2. above). Although it is most likely that the grower will use his own seed from the previous year's crop as he is accustomed to do, it will here be assumed that he purchases his additional seed requirements at a cost of, say, ¥12 (\$0.60)/kg. or a total cost of ¥24/rai (\$7.50/ha.).

Fertilizer:

Here it is assumed that the farmer uses no fertilizer for H. sabdariffa but that he applies 135 kg. of urea and 135 kg. of composite NPK fertilizer per hectare (21.5 kg. plus 21.5 kg. per rai) for H. cannabinus production (Section V.2.4.2. above). At the prevailing Government price of ¥3,800 (\$190.00)/metric ton, this is equivalent to an expenditure on fertilizer of ¥165/rai (\$51.60/ha.).

Weeding and Thinning:

As explained in Section 2.5.2. of this Chapter V, no weeding or thinning is required with H. cannabinus; on the other hand, these two operations are required and are very labor consuming as far as H. sabdariffa is concerned. However, since family labor is not costed in peasant farmer operations, no allowance is made for a production cost reduction, but such labor savings are offset against labor requirement increases for more intensive land preparation, for fertilizer application and for increased harvesting work as a result of higher yields per unit area.

Harvesting and Chopping:

Since it is assumed that H. cannabinus will produce twice the yield of H. sabdariffa, twice the labor per unit area should theoretically be required for its harvest; in practice, the additional labor requirement will be somewhat less, since a substantial portion of the yield increase is the result of larger kenaf stalks which require only minimally more labor to harvest than small stalks. At any rate, even a doubling of harvesting and chopping labor requirements would be more than offset by the savings in weeding and thinning labor.

Hence, additional H. cannabinus input costs amount to the following:

	<u>Baht/Rai</u>	<u>\$/Ha.</u>
Seed	24.00	7.50
Fertilizer	<u>165.00</u>	<u>51.60</u>
Total	<u>189.00</u>	<u>59.10</u>

Assuming then a (low) yield of 7.5 tons/ha. of H. sabdariffa stalks and a corresponding (low) yield of 15.00 tons/ha. of H. cannabinus stalks (Table I.16.) and a retted fiber price of P3.25/kg. for Mixed Grade at farm level, the respective gross revenues to the farmer from the sale of his kenaf would be as follows:

	<u>H. sabdariffa</u>	<u>H. cannabinus</u>
Stalk price per ton	¥498.00 (\$24.90)	¥498.00 (\$24.90)
Stalk yield per ha.	7.5 tons	15.00 tons
Gross revenue per ha.	\$186.75	\$373.50
Less seed & fertilizer costs	-	59.10
Adjusted gross revenue per ha.	<u>\$186.75</u>	<u>\$314.40</u>
Adjusted gross revenue per rai	<u>¥597.60</u>	<u>¥1,006.10</u>

The above comparison again emphasizes the paramount importance of increased yields upon the economics of kenaf for paper pulp production and makes it apparent that, for commercial plantation type operations, suitable soils must be selected which permit the production of the higher yielding H. cannabinus species.

Based upon the foregoing, it could be argued that in the Lower Mekong Basin, where all future kenaf for paper pulp will undoubtedly be produced by peasant farmers, the H. cannabinus grower could be offered a lower price than the H. sabdariffa grower without removing the incentive to grow the crop. However, apart from such considerations as fair treatment of the producer, a higher revenue is likely to be required to induce the H. cannabinus farmer to grow the crop since he might well have the option of planting higher value alternative crops on his better quality land than the H. sabdariffa farmer whose poorer quality land will economically produce little else but the Thai species of kenaf.

The same argument does, of course, apply to both whole stalk and bast ribbon production. Consequently, the same stalk and ribbon prices, per field dry metric ton, delivered local collection center, will be used in this Study for both kenaf species as follows:

Whole Kenaf Stalks = ¥ 498 (\$24.90)/FDMT;
Kenaf Bast Ribbon = ¥1,935 (\$96.75)/FDMT.

3. Kenaf Raw Material Purchasing and Handling Cost Estimates

In Chapter V, Section 3.4., three raw material procurement alternatives have been discussed, viz. through a mill owned and operated procurement organization, through the established kenaf baling plants and traders, and through cooperatives. The conclusion was reached that it would be both unwise and uneconomic to by-pass the balers and traders and have the mill handle its own purchasing; raw material purchasing through cooperatives presents a special case which will, however, assume importance only at a later stage. Nevertheless, the cost of operating mill owned collection centers is estimated herebelow for purposes of record and for possible application in connection with other project phases.

3.1. Pulp Mill Procurement Organization

3.1.1. Whole Stalk Raw Material

At the mill operated Collection Center and/or Depot (Chapter V, Section 3.4.1.), the field tied bundles of kenaf stalks delivered by oxcart by the small holders would be weighed and stacked to a height of, say, 8 meters. Investigations at the Bang Pa-In Paper Mill at Ayuthya, Thailand, and at two of its Collection Centers, for rice straw and Burma grass respectively, ascertained the following items of information (Note: all cost figures include weighing):

- | | |
|---|----------------------------|
| (i) 100 bales of 25 kg. each of rice straw
stacked to a height of 5 m. = $\text{P}17.00$
for 2.5 tons | $\text{P} 6.80/\text{ton}$ |
| (ii) 10 man-days to stack 20 tons/day
at $\text{P}20/\text{man-day}$ | 10.00/ton |
| (iii) $\text{P}0.15$ to stack 1 bale of 25 kg. of
rice straw at the Bang Pa-In Mill
yard = $\text{P}0.15 \times 1,000/25$ | 6.00/ton |
| (iv) Burma grass field bales stacked to
6 to 8 m. height at Bang Pa-In Mill
yard | 10.00/ton |

In view of the above information, Collection Center/Depot weighing and stacking expenses are assumed to amount to $\text{P}10.00$ (US\$0.50) per ton for purposes of cost estimation in this Study.

In order to estimate other Collection Center/Depot costs, the following assumptions are made:

- (i) Facility land rented; no permanent structures erected;
- (ii) 25 percent of the total stalk material purchases, or one-quarter of 206,000 tons = 51,500 tons, are shipped directly to the pulp mill, i.e. without storage at the Collection Centers/Depots;

- (iii) Each of the 24 Collection Centers/Depots will handle and store approximately 6,500 tons of stalks for an average period of 6 months;
- (iv) At the Collection Centers/Depots, the stalk field bundles will be stacked to a height of 8 m.; an area of 1 rai (0.16 ha.) will be required to stack 1,000 tons of stalks.

Overall Collection Center/Depot expenses, per ton of field dry whole stalks, are then estimated as follows:

	<u>Per FDMT</u>
(i) Weighing and stacking of incoming stalk bundles	฿10.00
(ii) Destacking, rebundling, and loading into trucks (labor and materials), at 150% of Item (i)	15.00
(iii) Overhead charges:	
Watchman: 6 man-months at ฿20/day	฿3,600
Depot Manager: Salary - 12 months at ฿1,000	12,000
Land rental: 7 rai at ฿100/year	700
Fencing	5,000
Thatching or waterproof covers for stalk stacks: ฿1.00/sq.m. = 6½ stacks at 1 rai = 6.5 x 1,600 sq.m. = 10,400 sq.m.	10,400
Insurance, at 2% of cost of stalks for 6 months	
= ฿500 x $\frac{6,500 \text{ tons}}{2}$ x $\frac{2}{100}$	<u>32,500</u>
Total for 6,500 tons of stalks	<u>฿58,300</u> 9.90

	<u>Per FDMT</u>
(iv) Handling loss = 2% on P500	<u>P10.00</u>
Total estimated Collection Center/ Depot Expenses	<u>P44.90</u> <u>=====</u>

Rounded off, the overall mill operated Collection Center/Depot expenses are then estimated at P45.00/FDMT = US\$2.25/FDMT of field tied bundles of whole kenaf stalks.

In Chapter V, Section 3.4.4., mention has been made of further compressing the above field tied bundles into reasonably high density bales in the existing kenaf fiber baling presses in Northeast Thailand. It was pointed out in that section that preliminary tests had shown that, without the stalks being crushed, a 300 to 400 kg./cu.m. bale density could be achieved and that considerably higher densities could be reached if the chopping plant at the pulp mill would not object to the stalks being crushed. Since the crushing of the stalks could conceivably cause problems at the pulp mill, it will be assumed, for purposes of this Study, that the whole stalks would only be medium density baled and that to an average bale density of 350 kg./cu.m.

If a mill operated purchasing organization were to undertake the press baling of the whole stalks, each of the 24 Collection Centers/Depots would then have to be equipped with one or two baling presses and auxiliary facilities such as are standard equipment in the existing more than 200 kenaf fiber baling plants in Thailand, most of them located in the Northeast. It is normally assumed that one such press can handle from 3,000 to 4,000 tons of retted kenaf fiber per season; there should be no problem in each unit baling between 4,000 and 5,000 tons of kenaf whole stalks during the more extended kenaf for paper pulp season so that a total of about 45 presses would be needed to bale the 206,000 tons of annual stalk requirements of the mill.

It is beyond the scope of this Study to establish the exact capital and operating costs of the required facilities in detail. Nevertheless, it appears from the foregoing that they would closely approximate those of a standard retted kenaf fiber baling plant. A check with some of the prominent Thai kenaf fiber balers established that, as of end-1975, these were estimated at approximately P1,000,000 (US\$50,000) per one-unit baling plant in capital costs, and at P0.40/kg. or P72 (\$3.60) per 181 kg. retted fiber bale in operating costs. It is considered justified that these operating costs should be reduced by one-third in the case of

whole stalk baling since such labor intensive operations as fiber grading, the removal of cuttings, and butt-end hackling required in retted fiber baling do not apply to whole stalk baling; all that would be required would be the cutting of the stalks into suitable lengths to fit the baling box of the press, and the pre-boxing of the stalks to speed up the loading. Hence, an operating cost of ¥48 (\$2.40) per whole stalk bale is assumed for a mill operated baling plant.

The foregoing demonstrates that the establishment of a mill operated whole stalk baling organization would be quite a costly proposition. It would require an estimated capital investment of ¥45 million (\$2.25 million); it would also result in estimated annual operating costs of ¥48 (\$2.40) x 206,000 tons x 5.5 bales/ton = ¥54.4 million (\$2,720,000), which, incidentally, are only slightly higher than those estimated above for field bundled whole stalk handling. Hence, the Consultants submit that press baling of whole stalks (as well as of chopped stalks and bast ribbon) must be considered within the context of raw material purchasing through the established baling plants, as discussed below in Section 3.2.

3.1.2. Chopped Stalk Raw Material

The handling of chopped kenaf stalks has been discussed in detail in Chapter V, Section 4.1. and 4.2., and the conclusion was reached that, under Lower Mekong Basin conditions, most of any chopped stalk raw material purchased by the pulp mill would be high-density baled before shipment from the production area to the mill site. If the chopped stalk raw material was to be purchased by a mill operated organization, it would again be necessary to equip the Collection Centers/Depots with baling presses and auxiliary facilities, where it is assumed that the same number of presses would be required as for whole stalk baling and that the operating costs would be identical.

Hence, chopped stalk raw material purchasing should also be handled through the established kenaf trading and baling organization, with the possible exception of minor quantities of bulk shipped stalk chips produced in close proximity to the pulp mill site.

3.1.3. Bast Ribbon Raw Material

Reference is here made to Chapter V, Sections 5.4., 5.5. and 5.6., where the problems of kenaf ribbon processing and handling are discussed in detail. The problem of purchasing and handling the mill's bast ribbon requirements through a mill operated purchasing organization would be very similar to although somewhat simpler than whole stalk and chopped stalk purchasing and handling, and would closely approach the standard retted kenaf fiber handling methods at the established Thai baling plants.

As explained in Chapter V, Section 5.5., it would be inconvenient and uneconomic to transport and store field baled kenaf ribbon and the conclusion was reached that all such ribbon would have to be high-density baled in the production area. As in the case of retted kenaf fiber, the ribbon "drums" or field bales would be delivered to the Collection Centers/Depots by the growers where they would be stored and high-density baled in the same manner as retted fiber. However, no quality grading, cutting removal and butt-end hackling would be required, but the ribbon would have to be pre-boxed to speed up the subsequent baling operation.

As for whole stalk and chopped stalk baling, it can again reasonably be assumed that a standard Thai kenaf baling press could handle between 4,000 and 5,000 tons of bast ribbon during the extended kenaf for paper pulp season. Since an annual total of 160,000 FDMT of bast ribbon are required by the 70,000 ADMT long fiber kenaf pulp mill (see Table I.17.), this means the installation of some 35 baling presses and auxiliary facilities. In this connection, it must be remembered that the 160,000 tons of ribbon would have to be purchased within more than twice the estimated radius from the mill site than whole stalk material, viz. 200 km. vs. 90 km. If the individual kenaf producers were then still to be assured a lead distance of not more than 15 km. for the delivery of their bast ribbon to the nearest Collection Center/Depot, a substantially larger number of depots would have to be established by the mill than for whole or chopped stalk purchases. It is suggested that simple Purchasing Stations be then organized at any required location beyond the maximum 35 Collection Centers/Depots to be equipped with baling presses and that the farmer delivered ribbon be transferred to the nearest such facility as soon as the individual Purchasing Station has accumulated one or two truck loads of ribbon.

Since, as in the case of whole stalk and chopped stalk raw material, the facilities required for ribbon baling would closely resemble those of a standard Northeast Thailand retted kenaf fiber baling plant, the same capital costs of ¥1,000,000 (\$50,000) are again assumed to apply to a one-unit baling plant as established in the foregoing Sub-Section 3.1.1. Similarly, operating costs are assumed to be one-third lower than those for retted fiber baling and to amount to ¥48 (\$2.40) per bale of 181 kg., inclusive of all items in the "Overall Collection Center/Depot Expenses" listed in Sub-Section 3.1.1. above.

The total capital costs of a mill operated ribbon purchasing and baling organization would then amount to an estimated 35 x ¥1 million = ¥35 million (\$1.75 million). Operating costs would amount to an estimated annual ¥48 (\$2.40) x 160,000 tons x 5.5 bales/ton = ¥42.2 million (\$2,110,000); to this would have to be added the cost of operation of possibly another 20 subsidiary Purchasing Stations.

3.2. Kenaf Baling Plants and Traders

As already discussed in detail in Chapter V of this Study, it is considered more convenient and more economical to the pulp mill, and more acceptable to all parties concerned with the kenaf trade as far as Thailand is concerned, if the mill would purchase its kenaf raw material requirements through the established kenaf baling plants and traders in Thailand and the agricultural produce traders in the other three riparian countries.

The pulp mill would then not only save the capital investment required for the establishment of its own network of Collection Centers/Depots/Baling Plants - estimated above at ¥45 million (\$2.25 million) for the whole stalk kenaf pulp mill and at ¥35 million (\$1.75 million) for the kenaf bast ribbon pulp mill - but it could also expect to realize a substantial saving in the baling charges themselves. In the past, the established kenaf balers in Northeast Thailand have usually been prepared to bale retted kenaf fiber supplied by the client on contract for an average of ¥20 (\$1.00) per bale in order to better distribute their overhead charges and more fully utilize their labor force and equipment. Since, as explained in the foregoing, the baling of whole stalks, stalk chips and bast ribbon requires substantially less labor than retted fiber baling, it is anticipated that, at least for purposes of their own cost calculations, the balers would assume an expenditure no greater than that amount for the baling operation and adjust their stalk or ribbon sales prices to the mill accordingly.

This Study assumes that 25 percent of the raw material purchases will be shipped directly to the pulp mill, i.e. without storage at the baling plants, but that the remaining 75 percent will be field stored, in this instance at the baling plants. Such storage would then involve:

75 Percent of 206,000 FDMT of Whole or Chopped Stalks	= 154,500 FDMT.
75 Percent of 160,000 FDMT of Bast Ribbon	= 120,000 FDMT.

Furthermore, storage time would average six months.

As pointed out in Chapter V, Section 3.4.2., the Northeast Thailand baling plants dispose of adequate storage facilities for their retted kenaf fiber and could use these facilities for the storage of the whole stalk, chopped stalk or bast ribbon raw material for the pulp mill, particularly since they would have to store the latter largely during the off-season for retted kenaf when most of their retted fiber has already been shipped to Bangkok.

Although storage costs, including interest on operating capital, are charged to the baling plants' normal overhead in the case of retted kenaf fiber, it seems advisable and, indeed, necessary for the pulp mill to make some allowance for such costs to the balers. In Section 3.1.1. above, the raw material handling expenses of a mill operated Collection Center/Purchasing Depot organization have been estimated at ₪45/FDMT (\$2.25/FDMT); it is suggested that, for purposes of this Pre-Feasibility Study, an identical allowance be made to the baling plants, but that this allowance should include the ₪20 (\$1.00) baling charges.

3.3. Cooperatives

The purchase of the pulp mills' raw material requirements through cooperatives has already been discussed in some detail in Chapter V, where particular reference has been made to the possible intensive production of kenaf for the mills at Sites I and II by the cooperatives in various strategically located Resettlement Areas of the Department of Public Welfare of the Thai Ministry of the Interior and where it is anticipated that farmers' cooperatives will progressively be able to increase the scope of their raw material supply as a result of various types of incentives offered by the mills (see Chapter V, Section 3.4.3.).

If the cooperatives then establish their own baling plants, the capital investment and operating costs per unit would be the same as those already estimated for the mill operated purchasing organization and it would probably be to their advantage to contract for stalk or bast ribbon baling with the established baling plants.

4. Kenaf Raw Material Transportation Cost Estimates

If the kenaf raw material purchases are handled by a mill operated organization, the mill will have to arrange for their transport from its Collection Centers/Depots to the mill site. Although it would, ultimately, be more economical for the mill to purchase its own fleet of trucks in view of the large quantities of material involved, transportation cost estimates will herein be based on the assumption that trucking equipment will be hired for that purpose.

Table VIII.6. shows the trucking rates charged by the Express Transport Organization (ETO), the Government trucking company in Thailand, as of September 1975 for 6-ton and 10-ton trucks respectively. The ETO states that the dimensions of the bodies of both truck sizes are identical, namely 5 m. x 2.50 m. x 2.40 m. = 30 cu.m. The transportation costs are then estimated as follows for the different types of kenaf raw materials and for the two sample Mill Sites I and II respectively.

A. Whole Kenaf Stalks, Mill Site I

In Chapter V, Section 3.3., a maximum transportation distance of 120 km. from Mill Site I was established to meet the whole stalk raw material requirements of the whole stalk kenaf pulp mill, assuming a 25 percent purchase rate of estimated available kenaf supplies within that distance from the mill (Fig. V.4.). To be conservative, it is assumed that the average lead from the mill is three-quarters of that maximum distance or 90 km.

In Chapter V, Section 3.4.4., the bulk density of whole stalk field bundles as prepared by the growers, was estimated at 100 to 120 kg./cu.m. or, say, 110 kg./cu.m. Since the 30 cu.m. truck body of either a 6-ton or 10-ton truck will then only hold $110 \times 30 = 3,300$ kg. or 3.3 tons, 6-ton trucks would be used for whole stalk transport because of their lower rental cost. This cost would amount to ¥560 for the average 90 km. lead distance (Table VIII.6.) and the estimated transportation cost for whole stalk field bundles would be $¥560/3.3$ tons = ¥169.70 or, say, ¥170.00/ton (\$8.50/ton).

In the same Chapter V, Section 3.4.4., the bulk density of press baled whole stalks was estimated at 300 to 400 kg./cu.m. or, say, an average of 350 kg./cu.m. This would permit the loading of $350 \times 30 = 10,500$ kg. or 10.5 tons into a 30 cu.m. truck body and 10-ton trucks

Trucking Rates, Express Transport Organization
September 1975

Distance (Km.)	6-Ton Truck				10-Ton Truck			
	Total Charge (฿)	Charge Per Km. (฿)	Charge Per Ton-Km.		Total Charge (฿)	Charge Per Km. (฿)	Charge Per Ton-Km.	
			฿	US ¢			฿	US ¢
50	400	8.00	1.33	6.65	550	11.00	1.10	5.50
60	440	7.33	1.22	6.10	600	10.00	1.00	5.00
75	500	6.67	1.11	5.55	675	9.00	0.90	4.50
100	600	6.00	1.00	5.00	800	8.00	0.80	4.00
120	680	5.67	0.95	4.75	900	7.50	0.75	3.75
150	800	5.33	0.89	4.45	1,050	7.00	0.70	3.50
170	880	5.18	0.86	4.30	1,150	6.76	0.67	3.35
200	1,000	5.00	0.83	4.15	1,300	6.50	0.65	3.25
220	1,080	4.91	0.82	4.10	1,400	6.36	0.64	3.20
250	1,200	4.80	0.80	4.00	1,550	6.20	0.62	3.10
270	1,280	4.74	0.79	3.95	1,650	6.11	0.61	3.05
300	1,400	4.67	0.78	3.90	1,800	6.00	0.60	3.00

Table VIII.6.

would then be used for the transport of press baled whole stalks. Transportation costs for the average lead distance of 90 km. would then amount to ₦750 per 10-ton truck (Table VIII.6.) and the estimated transportation cost for press baled whole stalks would be ₦750/10.5 tons = ₦71.43 or, say, ₦72.00/ton (\$3.60/ton).

B. Chopped Kenaf Stalks, Mill Site I

The lead distance for chopped kenaf stalks will, obviously, be the same as that for whole stalks or, say, 90 km. average.

In Chapter V, Section 4.2., the bulk density of high-density chopped stalk bales was established at 417 kg./cu.m. so that a 30 cu.m. truck body can hold 12,810 kg. or, say, 13 tons. Since the ETO - and certainly private truckers - will load up to 12 tons on a 10-ton truck, the estimated average transportation costs of baled chopped stalk by ETO trucks are estimated at ₦750/12 tons = ₦62.50/ton (\$3.15/ton).

As discussed in the same Section 4.2. of Chapter V, the bulk density of loose kenaf stalk ships is only 72 kg./cu.m. so that the 30 cu.m. truck body could carry only $72 \times 30 = 2,160$ kg. and average transportation costs, using a 6-ton truck, would then amount to $₦560/2.16$ tons = ₦260/ton (\$13.00/ton).

C. Kenaf Bast Ribbon, Mill Site II

In Chapter V, Section 5.3., a maximum road transportation distance of 270 km. from Mill Site II was estimated to meet the (South Asian kenaf) bast ribbon raw material requirements of the kenaf bast ribbon pulp mill at Site II. Assuming conservatively that the average transportation lead from the mill will be two-thirds of that maximum distance, an average 180 km. lead distance is assumed herein.

In Chapter V, Section 5.5., the bulk density of high-density bast ribbon bales was calculated at 576 kg./cu.m. and a 30 cu.m. truck body could hold $576 \times 30 = 17,280$ kg., but a maximum load of 12,000 kg. (12 tons) is again assumed for a 10-ton truck. The estimated average transportation costs of baled bast ribbon are then estimated at $₦1,200/12$ tons = ₦100/ton (\$5.00/ton) (see Table VIII.6.).

The above are the estimated transportation charges at the official ETO rates. On the other hand, a survey of probable transportation costs, as obtained from a number of private sources, provided the following information:

- (i) Mr. J. P. N.:
 ฿800 for 250 km. lead, 6 tons payload
 = ฿3.20/km. for 6-ton truck
- (ii) Northeast Jute Mills, Nakorn Ratchasima:
 ฿1,000 for 250 km. lead, 9.72 tons payload
 = ฿4.00/km. for 10-ton truck
- (iii) Manganese Transport:
 ฿2.80/km. for 10-ton truck
- (iv) Burma Grass Transport:
 ฿235 for 120 km. lead, 3.5 tons payload
 = ฿2.00/km. for 6-ton truck

Hence:

Average per 10-ton truck = ฿3.40/km. (\$0.17/km.)
Average per 6-ton truck = ฿2.60/km. (\$0.13/km.)

The official ETO and private carrier rates then compare as follows:

	<u>Rate Per Truck-Km.</u>	
	<u>฿</u>	<u>\$</u>
<u>6-Ton Truck</u>		
ETO - 100 km.	6.00	0.30
- 180 km.	5.11	0.26
Mr. J. P. N. - 250 km.	3.20	0.16
<u>Burma Grass - 120 km.</u>	<u>2.00</u>	<u>0.10</u>
Average - 163 km.	<u>4.10</u>	<u>0.21</u>

	<u>Rate Per Truck-Km.</u>	
	<u>₪</u>	<u>\$</u>
<u>10-Ton Truck</u>		
ETO - 100 km.	8.00	0.40
- 180 km.	7.00	0.35
Northeast Jute Mills - 250 km.	4.00	0.20
<u>Manganese - 180 km.</u>	<u>2.80</u>	<u>0.14</u>
Average - 332 km.	<u>5.45</u>	<u>0.27</u>

From the above, it would appear reasonable to assume that truck transportation costs will average out at:

6-Ton Truck = ₪5.00 (\$0.25) per km.
 10-Ton Truck = ₪6.00 (\$0.30) per km.

Referring then again to the different types of kenaf raw material and their respective bulk densities, average transportation charges for each type of raw material are estimated as follows:

	<u>Transportation Cost/Ton</u>	
	<u>₪</u>	<u>\$</u>
A. Whole Kenaf Stalks, Mill Site I		
A1. Field Bundled:		
₪5.00 x 90 km. divided by 3.3 tons	136.00	6.80
A2. Press Baled:		
₪6.00 x 90 km. divided by 10.5 tons	52.00	2.60
B. Chopped Kenaf Stalks, Mill Site I		
B1. In Bulk:		
₪5.00 x 90 km. divided by 2.16 tons	208.00	10.40
B2. Press Baled:		
₪6.00 x 90 km. divided by 12.0 tons	45.00	2.25
C. Kenaf Bast Ribbon, Mill Site II		
₪6.00 x 180 km. divided by 12.0 tons	90.00	4.50

5. Kenaf Raw Material Cost, Delivered Pulp Mill Yard Gate

Based upon the foregoing itemized purchasing, handling and transportation cost estimates, the total costs per field dry ton of kenaf raw material, delivered to the yard gate of the pulp mill, are summarized below. It is noted that the designations "Mill Site I" and "Mill Site II" are omitted in these cost estimate summaries, since it can safely be assumed that all of the various raw materials discussed could be delivered at identical costs to either one of these sites. For a mill operated purchasing organization, the pulp mill yard gate costs for the different types of kenaf raw material are then estimated as follows:

	<u>Cost/FDMT</u>	
	<u>¢</u>	<u>\$</u>
<u>A. Whole Kenaf Stalks</u>		
A1. Field Bundled:		
Purchase Price, Collection Center (Section 2.1.1.)	498	24.90
Collection Center Handling Costs (Section 3.1.1.)	45	2.25
Transportation Costs (Section 4.)	<u>136</u>	<u>6.80</u>
Estimated Mill Yard Gate Costs	<u>679</u> ===	<u>33.95</u> =====
A2. Press Baled:		
Purchase Price, Collection Center (Section 2.1.1.)	498	24.90
Collection Center Handling Costs (Section 3.1.1.)	48	2.40
Transportation Costs (Section 4.)	<u>52</u>	<u>2.60</u>
Estimated Mill Yard Gate Costs	<u>598</u> ===	<u>29.90</u> =====

		<u>Cost/FDMT</u>	
		<u>¢</u>	<u>\$</u>
B. <u>Chopped Kenaf Stalks</u>			
B1. In Bulk:			
Purchasing Price, Collection Center			
(Section 2.1.1.)	498		24.90
Collection Center Handling Costs			
(Assumed same as Whole Stalks)			
(Section 3.1.2.)	45		2.25
Transportation Costs (Section 4.)	<u>208</u>		<u>10.40</u>
Estimated Mill Yard Gate Costs	<u>751</u>		<u>37.55</u>
B2. Press Baled:			
Purchasing Price, Collection Center			
(Section 2.1.1.)	498		24.90
Collection Center Handling Costs			
(Assumed same as Whole Stalks)			
(Section 3.1.2.)	48		2.40
Transportation Costs (Section 4.)	<u>45</u>		<u>2.25</u>
Estimated Mill Yard Gate Costs	<u>591</u>		<u>29.55</u>
C. <u>Kenaf Bast Ribbon (Press Baled)</u>			
Purchasing Price, Collection Center			
(Section 2.1.2.)	1,935		96.75
Collection Center Handling Costs			
(Section 3.1.3.)	48		2.40
Transportation Costs (Section 4.)	<u>90</u>		<u>4.50</u>
Estimated Mill Yard Gate Costs	<u>2,073</u>		<u>103.65</u>

Since it has been assumed, in this Chapter VIII, that the raw material costs charged by the kenaf baling plants and traders to the pulp mill will be the same as those payable at the Collection Centers by a pulp mill operated purchasing organization and since an identical raw material handling allowance has been provided for the baling plants as for the Collection Centers (i.e. ¢45 = \$2.25/FDMT - see Section 3.2. above), the foregoing mill yard gate cost estimates apply equally to raw material purchases made through the established kenaf trading channels. However, purchasing through these channels would save the mill the investment in Collection Center/Purchasing Depot and baling

facilities ranging from \$2.1 to \$2.25 million (Section 3.1.1. and 3.1.3. above), possibly reduce transportation costs substantially by the more distantly located baling plants absorbing the transportation charge differential, and certainly assure the cooperation of the kenaf traders and balers (Chapter V, Section 3.4.2.).

Summarizing, the estimated mill yard gate costs, rounded off, for the different kenaf raw materials will be as follows:

	<u>Cost/FDMT</u>	
	<u>£</u>	<u>\$</u>
A. <u>Whole Kenaf Stalks</u>		
A1. Field Bundled	680	34.00
A2. Press Baled	600	30.00
B. <u>Chopped Kenaf Stalks</u>		
B1. In Bulk	750	37.50
B2. Press Baled	590	29.50
C. <u>Kenaf Bast Ribbon</u>	2,080	104.00

It will be seen that the cost, to the pulp mill, of press baled whole stalks and chopped stalks is practically the same; this is, of course, due to the fact that no additional cost allowance has been provided for the field or baling plant chopping of the stalks (Section 2.1.1. above). It is also clearly more economical for the mill to purchase press baled rather than field bundled whole kenaf stalks, although the estimated price difference might, in practice, be somewhat less than shown since the trucker may well attempt to transport more than the assumed 3.3 tons of stalk field bundles by further raising the side walls of the truck body. The above listing shows that it is clearly uneconomical to transport kenaf stalk chips in bulk under Lower Mekong Basin conditions.

The very much higher cost of the bast ribbon is, of course, due mostly to the fact that it is assumed in the above that, when bast ribbon is purchased, the stalk core material has no residual value; it is also assumed that, for bast ribbon, average transportation lead distances are twice those for whole stalks (180 km. vs. 90 km.). On the other hand, this Study further assumes a bleached pulp recovery rate of 45 percent for bast ribbon raw material as compared to a rate of 35 percent for whole stalk raw material.

6. Pulp Mill Demonstration Farm

The reasoning behind the establishment of a pulp mill operated kenaf demonstration farm, its organization and its operation have been described in Chapter V, Section 7. In this present section, the financial aspects of the basic 240 ha. (600 acres, 1,500 rai) Demonstration Farm "Unit" will be discussed in detail, including anticipated production costs for the three alternate kenaf raw materials - whole stalks, chopped stalks and bast ribbon - when produced on a mechanized "commercial" scale in the Mekong Basin area.

In order to simplify the preparation of the various tables in this Section 7, the financial aspects of the three production alternatives have been combined in these tables and the tabulations are justified and discussed in the following sub-sections.

6.1. Capital Costs

The estimated capital costs for the three kenaf raw material production alternatives are shown in Table VIII.7. The cost figures are based on investigations carried out in Bangkok during October/November 1975.

The estimated cost of ¥1,200 (US\$60.00) per hectare of land applies to uncleared farm land in the Ubon Ratchathani area of Northeast Thailand, the land being covered by semi-dense forest growth.

The prices for tractors and tractor implements, including the forage harvester, were obtained from the John Deere agency in Bangkok but similar information could, of course, have also been obtained from the agencies of other tractor and agricultural equipment manufacturers.

The high-crop harvester, a tractor front-mounted attachment, is manufactured in Denmark; the unit price shown was extrapolated from a known 1974 price. The ribboners are manufactured in Singapore and the price shown is that quoted as of end-1975.

The storage shed is a pre-fabricated steel building with corrugated iron siding and roofing and one large sliding door. The price shown includes a concrete floor and was quoted for the building installed in the Ubon Ratchathani area.

Land clearing and field road construction costs are averages as cited by the Farm Management Division of the Thai Ministry of Agriculture for Ubon Ratchathani Province.

The spare parts requirements for both the first and the second and subsequent years were estimated on the basis of the annual use to which the respective equipment would be submitted, as shown in Table V.16., Section 7.4. of Chapter V.

It will be seen in Table VIII.7. that the equipment and facility requirements for whole stalk and chopped stalk production are very similar, the only difference being that the two high-crop harvesters used in whole stalk production are replaced by a single forage harvester when chopped stalks are to be produced.

The capital costs for bast ribbon production, on the other hand, are approximately twice as great and that as a result of the requirement for six bast ribboners and their spare parts.

Capital Costs
240 Ha. Demonstration Farm Unit

Year	Item	Unit Cost (\$)	Total Cost (\$)		
			Whole Stalk Production	Chopped Stalk Production	East Ribbon Production
1	250 Hectares Land	60	15,000	15,000	15,000
	4 Tractors, John Deere, Model 2130, 79 HP.	12,500	50,000	50,000	50,000
	4 Sets Tractor Spares (20% of Tractor Cost)	2,500	10,000	10,000	10,000
	3 Disc-Plows, 4 Discs	1,200	3,600	3,600	3,600
	3 Sets Plow Spares (10% of Plow Cost)	120	360	360	360
	3 Disc-Harrows, 7 Discs	850	2,550	2,550	2,550
	3 Sets Harrow Spares (10% of Harrow Cost)	85	255	255	255
	1 Seed Drill, 21 Rows, w/Fertilizer Box	4,000	4,000	4,000	4,000
	1 Set Drill Spares (10% of Drill Cost)	400	400	400	400
	2 High-Crop Harvesters	6,000	12,000	-	12,000
	2 Sets Harvester Spares (10% of Harvester Cost)	600	1,200	-	1,200
	1 Forage Harvester, Pull-Type	4,000	-	4,000	-
	1 Set Harvester Spares (10% of Harvester Cost)	400	-	400	-
	6 Ribboners	22,600	-	-	135,600
	6 Sets Ribboner Spares (15% of Ribboner Cost)	3,400	-	-	20,400
	3 Trailers, 3 tons	2,000	6,000	6,000	6,000
	3 Sets Trailer Spares (10% of Trailer Cost)	200	600	600	600
	1 Truck, 5 tons	10,000	10,000	10,000	10,000
	1 Set Truck Spares (20% of Truck Cost)	2,000	2,000	2,000	2,000
	1 Storage Shed, 10 m. x 20 m. x 4 m. high	5,000	5,000	5,000	5,000
	- Land Clearing, 250 Ha.	160	40,000	40,000	40,000
	- Field Road Construction, 10 km.	150	1,500	1,500	1,500
	Sub-Total		164,465	155,665	315,965
	Contingencies (15%)		24,670	23,350	47,395
	Annual Cost		189,135	179,015	363,360
2, etc.	Spares (incl. installation):				
	Tractors - 3 Sets	2,500	7,500	7,500	-
	- 4 Sets	2,500	-	-	10,000
	Disc-Plows - 2 Sets	120	240	240	240
	Disc-Harrows - 2 Sets	85	170	170	170
	Seed Drill - 1 Set	400	400	400	400
	High-Crop Harvesters - 1 Set	600	600	-	600
	Forage Harvester - 1 Set	400	-	400	-
	Ribboners - 3 Sets	3,400	-	-	10,200
	Trailers - 1 Set	200	200	200	200
	Truck - 1 Set	2,000	2,000	2,000	2,000
	Sub-Total		11,110	10,910	23,810
	Contingencies (15%)		1,670	1,640	3,570
	Annual Cost		12,780	12,550	27,380

Table VIII.7.

The total capital costs for the 240 ha. Demonstration Farm Unit, including a 15 percent contingency reserve, are then estimated as follows:

	<u>1st Year</u>	<u>2nd Year, Etc.</u>
Whole Stalk Production	\$ 189,135	\$ 12,780
Chopped Stalk Production	179,015	12,550
Bast Ribbon Production	363,360	27,380

6.2. Operating Costs

These are detailed in Table VIII.8. Salaries and wages are based on those prevailing in Northeast Thailand at the end of 1975.

It is assumed that the general management of the Demonstration Farm or Farms will rest with the pulp mill management, so that only a practical Farm Manager will have to be assigned to each Demonstration Farm Unit. In fact, the Farm Manager in question could readily assume the responsibility for a larger Unit than the 240 ha. kenaf farm under discussion. He will be assisted by two Field Managers who will, in effect, be in charge of the different field operations. The Farm Manager and his two deputies would be employed on a year round basis.

The period of engagement of the tractor operators (drivers) and their helpers will depend on the type of raw material production. Reference is again made to Table V.16., Section 7.4. of Chapter V. For whole stalk and chopped stalk production, two tractor operators and their helpers will be required on a twelve months basis and the other two teams only for eight months each year. For bast ribbon production, on the other hand, all four tractor teams will be required throughout the year.

All three types of kenaf raw material harvesting/processing operations require four months, although at different times of the year, and the necessary unskilled labor will have to be engaged accordingly, as shown in Table VIII.8. Such labor requirements are identical for whole stalk and chopped stalk production, but they are very substantially greater for bast ribbon production in view of the thirteen-man team of attendants required by each bast ribboning machine in order to assure maximum ribboner output where the manual operations include stalk bundle assembly, stalk feeding, ribbon removal, ribbon spreading and removal after drying, and daily shifting of the movable drying lines. The ribboner capacity is such as to permit two five-man teams to attend the machine simultaneously. In addition, one ribboner operator will be required for each two ribboners, the operator's skill being about equivalent to that of a tractor driver.

The operating and maintenance costs are again based on the Tractor Operating Schedule in Table V.16. Hourly tractor operating costs are those cited by the John Deere agency in Bangkok for 1975 and confirmed by the Farm Management Division of the Thai Ministry of Agriculture. Ribboner operating costs per hour are estimated at some 60 percent of

Operating Costs
240 Ha. Demonstration Farm Unit

Year	Item	Unit Cost (\$)	Total Cost (\$)		
			Whole Stalk Production	Chopped Stalk Production	Best Ribbon Production
1, etc.	- Salaries & Wages				
	1 Farm Manager	125.00/Month	1,500	1,500	1,500
	2 Field Managers	75.00/Month	1,800	1,800	1,800
	4 Tractor Operators - 2 @ 12 Months, 2 @ 8 Months	50.00/Month	2,000	2,000	-
	- 4 @ 12 Months	50.00/Month	-	-	2,400
	4 Tractor Helpers - 2 @ 12 Months, 2 @ 8 Months	1.25/Day	1,250	1,250	-
	- 4 @ 12 Months	1.25/Day	-	-	1,500
	2 High-Crop/Forage Harvester Attendants - 4 Months	1.25/Day	250	250	250
	3 Whole Stalk/Chopped Stalk Harvesters - 4 Months	1.25/Day	375	375	-
	3 Ribboner Operators - 4 Months	50.00/Month	-	-	600
	60 Ribboner Attendants - 4 Months	1.25/Day	-	-	7,500
	18 Drying Line Attendants - 4 Months	1.25/Day	-	-	2,250
	- Operating & Maintenance Costs:				
	- Tractors & Implements:				
	93 Tractor-Weeks Plus 37 Tractor-Weeks General Transport				
	= 130 Tractor-Weeks @ 45 Hours				
	= 5,850 Tractor-Hours	3.50/Hour	20,475	-	-
	81 Tractor-Weeks Plus 34 Tractor-Weeks General Transport				
	= 115 Tractor-Weeks @ 45 Hours				
	= 5,175 Tractor-Hours	3.50/Hour	-	18,115	-
	101 Tractor-Weeks Plus 49 Tractor-Weeks General Transport				
	= 150 Tractor-Weeks @ 45 Hours				
	= 6,750 Tractor-Hours	3.50/Hour	-	-	23,625
	- Ribboners: 6 Units @ 16 Weeks @ 45 Hours				
	= 4,320 Ribboner-Hours	2.00/Hour	-	-	8,640
	1 Truck: 20,000 km./Year	0.15/km.	3,000	3,000	3,000
	1 Storage Shed (2% of Cost)	-	100	100	100
	1 Field Roads: 10 km. @ 10% of Construction Cost	15.00/km.	150	150	150
	- Seed: 240 Ha. x 25 Kg. = 6,000 Kg.	1.25/Kg.	7,500	7,500	7,500
	- Fertilizer: 135 Kg. Urea/Ha. = 240 Ha. = 32.4 tons	390.00/Ton	12,650	12,650	12,650
	135 Kg. 15:15:15/Ha. x 240 Ha. = 32.4 tons	270.00/Ton	8,750	8,750	8,750
	- Medical Services & Company Paid Social Security @ 10% of Salaries & Wages		720	720	720
	- Insurance		3,262	3,061	6,363
	Sub-Total		63,782	61,221	83,608
	Contingencies (15%)		9,563	9,184	12,542
	Annual Cost		73,345	70,405	96,150

tractor operating costs based upon the difference in horsepower of their respective diesel power units. The estimated operating costs for the 5-ton diesel truck at \$0.15 (¥3.00) per kilometer are considered conservative, particularly since they do not include spare parts.

The kenaf seed requirements are those established for H. cannabinus in Chapter V, Section 2.3.2. of this Study. Its estimated purchase price of \$1.25/kg. is that prevailing for H. cannabinus seed purchased from commercial producers in, say, Central America in 1975. The cost of seed production by the Demonstration Farm itself in subsequent years should be less than half the seed price shown.

Fertilizer requirements are those listed in Section 2.4.2. of Chapter V of this Study as they were estimated for H. cannabinus. The fertilizer prices quoted are the non-subsidized prices applicable for Northeast Thailand during the 1975 planting season.

The cost, to the Demonstration Farm, of medical services and company paid social security contributions, although not obligatory at this time in Thailand for small operations such as the Demonstration Farm Unit under discussion, have been estimated at some 10 percent of salaries and wages.

Insurance cost estimates have been obtained from a private insurance broker in Bangkok and are detailed in Table VIII.9. It is assumed that the produce is stored, on the average, for only six months at the farm since it will progressively be shipped to the pulp mill.

The total annual operating costs for the 240 ha. Demonstration Farm Unit, including a 15 percent contingency reserve, are then estimated as follows:

Whole Stalk Production	\$ 73,345
Chopped Stalk Production	70,405
Bast Ribbon Production	96,150

Insurance Costs
240 Ha. Demonstration Farm Unit

Item	Unit Cost (\$)	Total Cost (\$)			Insurance Rate (%)	Annual Insurance Cost (\$)		
		Whole Stalk Production	Chopped Stalk Production	Bast Ribbon Production		Whole Stalk Production	Chopped Stalk Production	Bast Ribbon Production
4 Tractors	12,500	50,000	50,000	50,000	2.50	1,250	1,250	1,250
- Tractor Implements:								
3 Disc-Plows	1,200	3,600	3,600	3,600				
3 Disc-Harrows	850	2,550	2,550	2,550				
1 Seed Drill	4,000	4,000	4,000	4,000				
2 High-Crop Harvesters	6,000	12,000	-	12,000				
1 Forage Harvester	4,000	-	4,000	-				
Sub-Total		22,150	14,150	22,150	2.00	443	283	443
6 Ribboners	22,600	-	-	135,600	2.00	-	-	2,712
3 Trailers	2,000	6,000	6,000	6,000	2.50	150	150	150
1 Truck, 5 tons	10,000	10,000	10,000	10,000	4.55	455	455	455
1 Storage Shed	5,000	5,000	5,000	5,000	2.00	100	100	100
- Produce:								
250 ha. x 15 tons = 3,600 tons	24.00 ⁽¹⁾	86,400	-	-	2.00	864 ⁽²⁾		
240 ha. x 15 tons = 3,600 tons	23.00 ⁽¹⁾	-	82,800	-	2.00		823 ⁽²⁾	
240 ha. x 3.6 tons = 864 tons	145.00 ⁽¹⁾	-	-	125,280	2.00			1,253 ⁽²⁾
Total						3,262	3,061	6,363

Note: (1) Approx. Production Costs
(2) Based on 6 Months Storage Only

Table VIII.9.

6.3. Profit & Loss Estimate

The Profit & Loss Estimate for the 240 ha. Demonstration Farm Unit is shown in Table VIII.10. The operating costs are as estimated in Table VIII.8. and the depreciation as shown in Table VII.11.

Revenues have been assumed at a level of 20 percent above total (production) costs. This is, of course, an arbitrary figure, since the Demonstration Farm is not designed to be a profit making enterprise. However, this revenue figure will permit the Farm Unit to recover its cash investment in the tenth to fifteenth year of operation (see Table VIII.12.).

At the total costs and revenues shown in Table VIII.10., the production costs and sales prices per ton (ex farm gate) will then be as follows:

	<u>Production Cost/Ton</u>	<u>Sales Price/Ton</u>
Whole Stalk Production*	\$ 24.00	\$ 28.80
Chopped Stalk Production*	22.90	27.50
Bast Ribbon Production**	146.10	175.30

* 240 ha. x 15 tons/ha. = 3,600 tons total production
** 240 ha. x 3.6 tons/ha. = 864 tons total production

Profit & Loss Estimate
240 Ha. Demonstration Farm Unit

Year	Operating Costs (Table VIII.8)	Depreciation (Table VIII.11)	Total Costs	Revenue (1)	Annual Profit	Cumulative Profit
A. Whole Stalk Production						
1	\$73,345	\$13,120	\$ 86,465	\$103,758	\$17,293	\$ 17,293
2	73,345	13,120	86,465	103,758	17,293	34,586
3	73,345	13,120	86,465	103,758	17,293	51,879
4	73,345	13,120	86,465	103,758	17,293	69,172
5	73,345	13,120	86,465	103,758	17,293	86,465
6	73,345	13,120	86,465	103,758	17,293	103,758
7	73,345	13,120	86,465	103,758	17,293	121,051
B. Chopped Stalk Production						
1	\$70,405	\$12,120	\$ 82,525	\$ 99,030	\$16,505	\$ 16,505
2	70,405	12,120	82,525	99,030	16,505	33,010
3	70,405	12,120	82,525	99,030	16,505	49,515
4	70,405	12,120	82,525	99,030	16,505	66,020
5	70,405	12,120	82,525	99,030	16,505	82,525
6	70,405	12,120	82,525	99,030	16,505	99,030
7	70,405	12,120	82,525	99,030	16,505	115,535
C. Bast Ribbon Production						
1	\$96,150	\$30,070	\$126,220	\$151,464	\$25,244	\$ 25,244
2	96,150	30,070	126,220	151,464	25,244	50,488
3	96,150	30,070	126,220	151,464	25,244	75,732
4	96,150	30,070	126,220	151,464	25,244	100,976
5	96,150	30,070	126,220	151,464	25,244	126,220
6	96,150	30,070	126,220	151,464	25,244	151,464
7	96,150	30,070	126,220	151,464	25,244	176,708

Note: (1) Production Costs + 20% Profit, Ex Farm

Table VIII.10.

Depreciation
240 Ha. Demonstration Farm Unit

Item	Unit Cost (\$)	Total Cost (\$)			Depreciation Rate (%)	Annual Cost of Depreciation (\$)		
		Whole Stalk Production	Chopped Stalk Production	Best Ribbon Production		Whole Stalk Production	Chopped Stalk Production	Best Ribbon Production
4 Tractors	12,500	50,000	50,000	50,000	15	7,500	7,500	7,500
- Tractor Implements								
3 Disc-Plows	1,200	3,600	3,600	3,600				
3 Disc-Harrows	850	2,550	2,550	2,550				
1 Seed Drill	4,000	4,000	4,000	4,000				
2 High-Crop Harvesters	6,000	12,000	-	12,000				
1 Forage Harvester	4,000	-	4,000	-				
Sub-Total		22,150	14,150	22,150	12½	2,770	1,770	2,770
6 Ribboners	22,600	-	-	135,600	12½	-	-	16,950
3 Trailers	2,000	6,000	6,000	6,000	10	600	600	600
1 Truck, 5 tons	10,000	10,000	10,000	10,000	20	2,000	2,000	2,000
1 Storage Shed	5,000	5,000	5,000	5,000	5	250	250	250
Annual Depreciation Costs						<u>13,120</u>	<u>12,120</u>	<u>30,070</u>

Table VIII.11.

6.4. Cashflow Estimate

The cashflow estimate for the 240 ha. Demonstration Farm Unit is shown in Table VIII.12. The figures shown in brackets represent negative cash balances.

It will be seen that the Demonstration Farm Unit under discussion will recover its cash investment after the following periods:

	<u>Year of Operation</u>
Whole Stalk Production	10
Chopped Stalk Production	11
Bast Ribbon Production	15

Cashflow Estimate
240 Ha. Demonstration Farm Unit

Item	Revenue (1)	Capital Costs	Operating Costs	Total Expenditures	Cash Balance	Cash Balance Carried Forward
A. Whole Stalk Production						
1	\$103,758	\$189,135	\$73,345	\$262,480	(\$158,722)	(\$158,722)
2	103,758	12,780	73,345	86,125	17,633	(141,089)
3	103,758	12,780	73,345	86,125	17,633	(123,456)
4	103,758	12,780	73,345	86,125	17,633	(105,823)
5	103,758	12,780	73,345	86,125	17,633	(88,190)
6	103,758	12,780	73,345	86,125	17,633	(70,557)
7	103,758	12,780	73,345	86,125	17,633	(52,924)
B. Chopped Stalk Production						
1	\$ 99,030	\$179,015	\$70,405	\$249,420	(\$150,390)	(\$150,390)
2	99,030	12,550	70,405	82,955	16,075	(134,315)
3	99,030	12,550	70,405	82,955	16,075	(118,240)
4	99,030	12,550	70,405	82,955	16,075	(102,165)
5	99,030	12,550	70,405	82,955	16,075	(86,090)
6	99,030	12,550	70,405	82,955	16,075	(70,015)
7	99,030	12,550	70,405	82,955	16,075	(53,940)
C. Bast Ribbon Production						
1	\$151,464	\$363,360	\$96,150	\$459,510	(\$308,046)	(\$308,046)
2	151,464	27,380	96,150	123,530	27,934	(280,112)
3	151,464	27,380	96,150	123,530	27,934	(252,178)
4	151,464	27,380	96,150	123,530	27,934	(224,244)
5	151,464	27,380	96,150	123,530	27,934	(196,310)
6	151,464	27,380	96,150	123,530	27,934	(168,376)
7	151,464	27,380	96,150	123,530	27,934	(140,442)

Note: (1) See Table VIII.10.

Table VIII.12.

CHAPTER IX - ESTIMATED PRODUCTION COSTS, CAPITAL REQUIREMENTS,
PROFITABILITY, AND ECONOMIC VALUES OF A KENAF PAPER
MILL IN THE MEKONG BASIN AREA

1. Introduction

A pre-feasibility study for a pulp mill of this nature must be based upon a realistic appraisal of all factors involved, including the financial and economic ones. In the case of developing countries, where the needs, hopes, and aspirations of many of the people are based upon the viability and success of given regional projects, the disclosure of meaningful economic and financial information is of necessity. In this regard, it must be recognized that there have been innumerable such projects that have ended in financial disasters because the true picture relative to raw material supply, technical resource requirements, operating and production costs, capital needs, etc. have been underestimated, indicating a far more viable project than is actually possible. This has happened both in large industrialized countries where mistakes in planning can easily be absorbed by the economy as well as in countries of limited resources for industrial development where the results in some instances have been catastrophic.

In considering the possibilities for developing a kenaf paper pulp mill in the Mekong Basin area, where no such plant exists and regional price data are not available, it has been necessary to consider the actual turn key costs for a number of relatively similar pulp and paper mill complexes that have recently been proposed and are under construction in some of the developing countries. The projected level of costs for such actual mill installations at the present time indicates that the estimated investment requirements for a kenaf bleached pulp mill, as given in Section 6.2. of Chapter I of this Study, are very conservative for the mill project in the Mekong Basin area. Also, it must be emphasized that any future consideration of these data on the cost of building pulp mills will have to take into account the continuing price increases that will occur between the time of the preparation of this report at the end of 1975 and the time of its definition, the final economic decision, and possible implementation.

2. Development of the Estimated Production Costs of the Mekong Basin Project Kenaf Pulp Mill

A detailed manning table of the personnel requirements and costs thereof has been prepared for this project, and the data are summarized in Table IX.1. It is estimated that approximately 781 local workers would be required to operate the enterprise at the mill and corporate offices. The large number of 320 kenaf handling workers should be noted. They are required at the mill storage yard to handle, in and out of storage, approximately 25 percent of the annual supply of fibrous raw material in the form of bales of field dried kenaf.

The cost of the service of the Foreign Technical Assistance Team has also been included in the total labor cost estimates. This cadre of foreign specialists will be required to bring the mill to full operating capacity as soon as is practically possible.

Estimates of direct production costs for both kenaf whole stalk and bast ribbon bleached pulps have been made and the data are given in Tables IX.2. and IX.3.

The kenaf fibrous raw material costs are those developed in the agro-economic sections of this Study.

The requirements for chemicals have been developed on the basis of the technical parameters for producing the two types of pulps as outlined in Table VII.1., Section 5. of Chapter VII of this Study. Delivered prices for chemicals include applicable rail freight to the proposed Mill Sites I and II in the Mekong Basin area, and are those which prevailed in Thailand in August 1975 when the field trip for the pulp mill sections of this Study was made. The lower requirement for chlorine and its compounds for bleaching when producing bast ribbon pulp as compared to the requirements for whole stalk pulp should be noted. The excess chlorine available should be easily marketed locally.

In developing the cost for utilities for the mill complex, including townsite, it has been assumed that the enterprise will be tied into the national power grid for standby power only. Any "borrowed" electric power would be returned to the national grid by the mill when convenient to both parties. The power required for the mill would be generated mainly by a back-pressure turbo-generator with steam extraction at two levels as required for the mill process. An auxiliary turbo-generator operating with a condenser to supply additional electric power required over that generated by the main turbo-generator would also be used in the mill's utility system.

Table IX.1.(A)

Salaries and Wages for Mekong Project Kenaf Paper Pulp Mill
Management and Operating Staff and Cost of Foreign
Technical Assistance Team

<u>Department</u>	<u>Number of Persons</u>	<u>Annual Total Cost of Wages and Salaries and Fringe Benefits for Mekong Personnel</u>	
		<u>Local (₱/Year)</u>	<u>Foreign (US\$/Year)</u>
<u>Administration</u>			
Executive Office	9	2,219,900	-
Mill Management	19	1,543,900	-
Engineering	7	549,700	-
Personnel Office	3	268,600	-
Research and Control			
Laboratory	32	1,313,600	-
Mill Office	16	652,400	-
Operations Supervision	14	1,638,400	-
Sub-total	100	8,185,900	-
<u>Mill Operation</u>			
Skilled Workers	131	5,161,300	-
Semiskilled Workers	138	3,883,700	-
Unskilled Workers	92	1,294,600	-
Kenaf Handling Workers	320	2,701,700	-
Sub-total	681	13,041,300	-
 Total	 781	 ₱21,227,200	 (US\$1,061,400 equivalent)
<u>Technical Assistance</u>	<u>Number of Persons</u>	<u>Annual Total Cost of Salaries and Local Support for Technical Assistance Team</u>	
		<u>Local (₱/Year)</u>	<u>Foreign (US\$/Year)</u>
<u>Foreign Team</u>			
Years 1 & 2	18	1,512,000	plus 718,200
Total		(₱15,876,000 equivalent)	or (US\$793,800 equivalent)
Years 3 & 4	9	756,000	plus 359,100
Total		(₱7,938,000 equivalent)	or (US\$396,900 equivalent)

Table IX.1.(B)

Salaries and Wages for Mekong Project Kenaf Paper Pulp Mill
Management and Operating Staff and Cost of Foreign
Technical Assistance Team
(Continued)

<u>Total Labor Cost Summary</u>			
<u>Years of Operation</u>	<u>Item</u>	<u>Labor Cost Based on Pulp Product Unit</u>	
		<u>Local (฿/ADMT)</u>	<u>Foreign (US\$/ADMT)</u>
1 & 2	All Mekong Personnel	303	-
	Tech. Asst. Team	<u>22</u>	plus 10.26
	Sub-total	<u>325</u>	plus 10.26
	Total	(฿530 equivalent)	or (US\$26.50 equivalent)
3 & 4	All Mekong Personnel	303	-
	Tech. Asst. Team	<u>11</u>	plus 5.13
	Sub-total	<u>314</u>	plus 5.13
	Total	(฿417 equivalent)	or (US\$20.85 equivalent)
5-15	All Mekong Personnel	303	-
	Tech. Asst. Team	<u>0</u>	plus 0
	Sub-total	<u>303</u>	plus 0
	Total	(฿303 equivalent)	or (US\$15.15 equivalent)

Note: These total salaries and wages for Mekong mill personnel are based on the rates used in government and privately-owned pulp and paper mills in Thailand in 1975. The operating labor force is set up for four complete groups working eight hour shifts for five days a week with one extra swing shift per week. Pay is for 52 weeks a year and the perquisite (fringe benefit) for all mill local employees is 23 percent additionally, allowing for 31 paid days for vacation, sick leave, and holidays and including basic medical care, worker transportation or housing maintenance and utilities, safety equipment, and social welfare and miscellaneous benefit costs.

The cost for the Foreign Technical Assistance Team will be in effect for the first two years of operation and will be half that total cost for the next two years. It will be terminated at the end of the first four years of operation of the mill.

Table IX.2.

Estimated Direct Production Cost at Full Operating Rate
of Kenaf Whole Stalk Bleached Paper Pulp in
Mekong Basin Project Mill

<u>Item</u>	<u>Annual Requirements</u>		<u>Unit Cost</u>	<u>Annual</u>
	<u>Amount</u>	<u>Unit</u>	<u>at Mill</u>	<u>Total Cost</u>
			<u>(Equi. US\$)</u>	<u>(Equi. US\$/Year)</u>
<u>1. Fibrous Raw Material</u>				
Kenaf Whole Stalk	205,714	FDMT	30.00	6,171,400
<u>2. Chemicals</u>				
Salt (95% NaCl)	9,730	MT	20.50	199,500
Salt Cake (95% Na ₂ SO ₄)	1,373	MT	130.50	179,200
Limestone (85% CaCO ₃)	10,885	MT	7.50	81,600
Sulfur	350	MT	81.00	28,400
Alum (Dry)	1,885	MT	146.00	270,800
Coagulant Aid	4	MT	5,510.00	22,000
Misc. Chemicals & Defoamers				<u>50,000</u>
			Chemicals Sub-total	831,500
<u>3. Utilities for Mill and Townsite</u>				
Water (Before Treatment)	15.6 X 10 ⁶	cu. m.	0	0
Power (Standby Charge)	2,500	kw.	27.60	69,000
Lignite	166,320	MT	15.50	2,578,000
(Oil-Alternative)	(55,440)	MT	90.00	(4,989,000)
			Utilities Sub-total	2,647,000
<u>4. Salaries, Wages, and Perquisites</u>				
Total for Mekong Personnel		-	-	1,061,400
Technical Assistance				
(Foreign Personnel)	Years 1 & 2			793,800
	Years 3 & 4			396,900
<u>5. Maintenance and Operating Materials and Supplies for Mill & Townsite</u>				
Estimated				1,800,000
<u>6. Contingencies</u>				
10% of Item 5				180,000
<u>7. Insurance on Fibrous Raw Material in Mill Storage</u>				
For Kenaf Whole Stalk Stored in Mill Yard				30,900

Table IX.3.

Estimated Direct Production Cost at Full Operating Rate of
Kenaf Bast Ribbon Bleached Paper Pulp in Mekong
Basin Project Mill

<u>Item</u>	<u>Annual Requirements</u>		<u>Unit Cost</u>	<u>Annual</u>
	<u>Amount</u>	<u>Unit</u>	<u>at Mill</u>	<u>Total Cost</u>
			<u>(Equi. US\$)</u>	<u>(Equi. US\$/Year)</u>
<u>1. Fibrous Raw Material</u>				
Kenaf Bast Ribbon	160,000	FDMT	104.00	16,640,000
<u>2. Chemicals</u>				
Salt (95% NaCl)	9,730	MT	20.50	199,500
Salt Cake (95% Na ₂ SO ₄)	1,373	MT	130.50	179,200
Limestone (85% CaCO ₃)	9,643	MT	7.50	72,300
Sulfur	350	MT	81.00	28,400
Alum (Dry)	1,885	MT	146.00	270,800
Coagulant Aid	4	MT	5,510.00	22,000
Miscellaneous Chemicals and Defoamers				50,000
Anticipated Revenue from Sale of Excess Chlorine (In Sales)	1,750	MT	(350.00)	(612,500)
Chemicals Sub-total				822,200
<u>3. Utilities for Mill and Townsite</u>				
Water (Before Treat- ment)	15.6 X 10 ⁶	cu. m.	0	0
Power (Standby Charge)	2,500	kw.	27.60	69,000
Lignite	166,320	MT	15.50	2,578,000
(Oil-Alternative)	(55,440)	MT	90.00	(4,989,600)
Utilities Sub-total				2,647,000
<u>4. Salaries, Wages, and Perquisites</u>				
Total for Mekong Personnel				1,061,400
Technical Assistance (Foreign Per- sonnel)	Years 1 & 2			793,800
	Years 3 & 4			396,900
<u>5. Maintenance and Operating Materials and Supplies for Mill & Townsite</u>				
Estimated				1,800,000
<u>6. Contingencies</u>				
10% of Item 5				180,000
<u>7. Insurance on Fibrous Raw Material in Mill Storage</u>				
For Kenaf Bast Ribbon Stored in Mill Yard				83,200

In the cost analysis for various fuels, including kenaf woody core material that might be available to the mill, as discussed in Section 4. of Chapter I of this Study, it was shown that lignite available in Thailand would be far more economical and advantageous for the mill than fuel oil which would have to be imported. Because of this very important factor, capital as well as operating costs for this project are based upon the utilization of lignite for generation of steam beyond that produced in the chemical recovery system by burning the spent pulping liquor. The total fuel requirements for kenaf pulp production are based upon the same parameters of steam and power usage by modern and completely integrated nonwood plant fiber bleached chemical pulp mills, including the generation of bleaching chemicals and power supply to the townsite.

3. Estimated Total Capital Requirements to Establish a Kenaf Paper Pulp Mill

The estimated total capital requirements to establish a plant complex capable of making both kenaf whole stalk and bast ribbon bleached pulp for the local market or export have been developed, as previously mentioned, on the basis of recent studies for similar installations in developing nations. A summary of these estimated requirements is given in Table IX.4.

In establishing the data for equipment costs, it should be noted that 1975 quotations for the major items of pulp making as well as other process equipment that would be manufactured in the major machinery producing countries of the world have been used. The cost of the housing community and facilities was based on estimates for similar buildings and infrastructure prevailing in Thailand in mid-1975.

The costs of other tangible services required to build, erect, and start up the complex and that would be capitalized were developed using average percentage parameters which have been found to be applicable in several recent pulp mill projects in which foreign consortiums of contractors offered to undertake undivided global responsibility for establishing a complete turn-key project in a developing country.

In determining the foreign and local capital requirements, it was established that the ratios were adequate to support debt to equity ratios that may be acceptable to the international financial community and within the realm of possibilities of the local equity investor. In this project, the total capital requirements for both foreign and local funds would be equivalent to US\$81,284,000 of which US\$53,700,000 would be required in foreign currency and US\$27,534,000 (¥550,680,000) in local funds or 33.87 percent of the total needs.

It would, therefore, appear that this 2:1 debt to equity ratio should be more than adequate to obtain favorable endorsement by all concerned.

It should be noted that, in consideration of the size mill involved, the total capital requirements of US\$406,000 per ADMT per day of installed capacity, including working capital, is a very realistic value for such a turn-key project, when compared to the data in Figure I.2. in Section 6.2. of Chapter I of this Study.

Table IX.4.

Estimated Total Capital Requirements to
Establish a Kenaf Paper Pulp Mill
in the Mekong Basin Area

Item	Capital Requirements (Equivalent US\$)		
	Foreign	Local	Total
Land (a)	-	175,000	175,000
Site Development		1,125,000	1,125,000
Plant Buildings & Structures	550,000	4,950,000	5,500,000
Total Land & Plant Civil Works	550,000	6,250,000	6,800,000
Imported Machinery & Equipment	32,300,000	700,000	33,000,000
Locally Constructed Machinery & Equipment	-	5,700,000	5,700,000
Total Machinery & Equipment (b)	32,300,000	6,400,000	38,700,000
Spare Parts & Consumables	3,200,000	600,000	3,800,000
Erection Labor, Materials, & Supervision	2,900,000	3,600,000	6,500,000
Engineering & Technical Services	3,800,000	400,000	4,200,000
Personnel Training Abroad	300,000	100,000	400,000
Prestart-up Expenses	400,000	1,400,000	1,800,000
Start-up Expenses	1,200,000	400,000	1,600,000
Contingency (c)	4,200,000	1,800,000	6,000,000
Interest During Construction (d)	4,900,000	-	4,900,000
Total of Other Items to Be Capitalized for Plant	20,900,000	8,300,000	29,200,000
Total Cost of Implementing the Pulp Mill	53,750,000	20,950,000	74,700,000
Housing Community & Facilities		3,357,000	3,357,000
Estimated Total Cost of Fixed Assets	53,750,000	24,307,000	78,057,000
Working Capital (e)			
Kenaf Whole Stalk Mill		3,227,000	3,227,000
(Kenaf Bast Ribbon Mill)		(5,844,000)	(5,844,000)
Estimated Total Capital Required to Establish the Project at Start-up			
Kenaf Whole Stalk Mill (f)	53,750,000	27,534,000	81,284,000
(Kenaf Bast Ribbon Mill)	(53,750,000)	(30,151,000)	(83,901,000)

- Notes:
- (a) Includes site for community housing.
 - (b) Including ocean and inland freight and insurance. This is total cost of machinery and equipment delivered to the site. It is assumed there are no import duties for a promoted investment.
 - (c) This covers unforeseen expenses and escalation during construction.
 - (d) Interest on local items during construction would not be charged as all funds for local costs would be furnished as equity capital.
 - (e) The inventory of kenaf bast ribbon in storage at the mill results in a working capital requirement increase equivalent to US\$2,617,000 over that required for the whole stalk kenaf pulp mill. This would be borrowed locally at 10% interest and repaid as soon as possible from funds generated by the mill.
 - (f) On the basis that all local capital requirements will come out of equity, the owners' equity in this project will be 33.87% of the total capital required to establish the project at start-up.

4. The Estimates of Profitability for Kenaf Paper Pulp Mills

In developing the profit and loss statements, the schedule of interest and amortization of debt on foreign loans has been computed as shown in Table IX.5. It is believed that the maximum time that will be granted for a foreign loan on this type of a project would be limited to about 10 years from the start of commercial operations and that an interest rate on the order of 10 percent would have to be paid. Such a high rate of interest obviously discounts the loss of monetary value, due to inflation on the amount borrowed.

The schedule of depreciation for the project is as shown in Table IX.6. The depreciation over a 20 year period for buildings and structures is that allowed by the Government of Thailand. The choice of the 15 year straight line depreciation method for other depreciable items, including machinery and capitalized tangible expenses and pre-start-up interest, has been made in view of the favorable corporate income tax holiday granted by the Board of Investment of Thailand for Promoted Enterprises in the Special Investment Zones where the project mill would be located.

In essence, the straight line method of depreciation gives a lower capital recovery in the early years of a project than the sum-of-the-years digits or double-declining-balance methods. Thus, it is more advantageous than the latter methods in a situation where a corporate income tax holiday is granted for the early years of the project.

In developing the data for the estimated profitability of the pulp mill making either type of kenaf pulp, four complete sets of profit and loss statements and estimated profitability analyses have been prepared and summarized. For this Study, only one detailed set of the financial analyses, that for kenaf whole stalk pulp (at zero inflation factor) has been included as a sample of calculations. These data and calculations are given in Table IX.7, and IX.9.

Table IX.8. details the explanatory notes for all four cases that have been analyzed. These detailed notes relate directly to all aspects of the financial analyses so are not repeated in this text, except that more elaborate explanations of two important items are offered as discussed below.

Schedule of Interest and Amortization
of Debt on Foreign Loans

Payments Installment Number	Due Date of Payments (Months after Loan Commitment)	Amount Outstanding (Equiv. US\$)	Items of Payment (Equivalent US\$)		
			Principal	Interest	Total
1*	42	53,750,000	-	2,687,500	2,687,500
2	48	53,750,000	2,687,500	2,687,500	5,375,000
3	54	51,062,500	2,687,500	2,553,120	5,240,620
4	60	48,375,000	2,687,500	2,418,750	5,106,250
5	66	45,687,500	2,687,500	2,284,370	4,971,870
6	72	43,000,000	2,687,500	2,150,000	4,837,500
7	78	40,312,500	2,687,500	2,015,620	4,703,120
8	84	37,625,000	2,687,500	1,881,250	4,568,750
9	90	34,937,500	2,687,500	1,746,870	4,434,370
10	96	32,250,000	2,687,500	1,612,500	4,300,000
11	102	29,262,500	2,687,500	1,463,120	4,150,620
12	108	26,875,000	2,687,500	1,343,750	4,031,250
13	114	24,187,500	2,687,500	1,209,370	3,896,870
14	120	21,500,000	2,687,500	1,075,000	3,762,500
15	126	18,812,500	2,687,500	940,620	3,628,120
16	132	16,125,000	2,687,500	806,250	3,493,750
17	138	13,437,500	2,687,500	671,870	3,359,370
18	144	10,750,000	2,687,500	537,500	3,225,000
19	150	8,062,500	2,687,500	403,120	3,090,620
20	156	5,375,000	2,687,500	268,750	2,956,250
21	162	2,687,500	2,687,500	134,370	2,821,870

*Note: Theoretical start-up date of the mill. Rate of interest is 10%.
Principal payment is not made until the second installment. Principal and interest payments are made every 6 months.

Table IX.6.

Schedule of Depreciation for Depreciable
Capital Goods and Services

<u>Item</u>	<u>Amount for Straight Line Depreciation (Equivalent US\$)</u>	
	<u>Total</u>	<u>Annual</u>
<u>Capital in Items Depreciated over 20 Years at 5% Annually</u>		
Site Development	1,125,000	
Plant Building & Structures	5,500,000	
Housing Community and Facilities	<u>3,357,000</u>	
Sub-total Depreciable Assets	9,982,000	
Sub-total Annual Depreciation		499,000
<u>Capital in Items Depreciated over 15 Years at 6.66% Annually</u>		
Machinery & Equipment	38,700,000	
Erection Labor, Materials & Supervision	6,500,000	
Engineering & Technical Services	4,200,000	
Personnel Training Abroad	400,000	
Prestart-up Expenses	1,800,000	
Start-up Expenses	1,600,000	
Contingency	6,600,000	
Interest During Construction	<u>4,968,000</u>	
Sub-total Depreciable Assets	64,168,000	
Sub-total Annual Depreciation		4,274,000
Total Depreciable Assets	74,150,000	
Total for Annual Depreciation		4,773,000

Table IX. 7.

Estimated Profit and Loss Statement
Kenaf Whole Stalk Bleached Paper Pulp
(Zero Inflation Factor)

Operating Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Pulp Production (ADMT/Year)	49,000	59,500	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000
Delivered Pulp Price (Equi. US\$/ADMT)	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
	(Equivalent US\$-1,000)														
<u>Sales Revenue</u>															
Bleached Pulp	22,050	26,775	31,500	31,500	31,500	31,500	31,500	31,500	31,500	31,500	31,500	31,500	31,500	31,500	31,500
<u>Cost of Sales</u>															
Direct Production Cost:															
Variable Expenses	6,707	8,144	9,581	9,581	9,581	9,581	9,581	9,581	9,581	9,581	9,581	9,581	9,581	9,581	9,581
Fixed Expenses	3,935	3,935	3,538	3,538	3,141	3,141	3,141	3,141	3,141	3,141	3,141	3,141	3,141	3,141	3,141
Sub-Total	10,642	12,079	13,119	13,119	12,722	12,722	12,722	12,722	12,722	12,722	12,722	12,722	12,722	12,722	12,722
Selling Expense	213	242	262	262	254	254	254	254	254	254	254	254	254	254	254
Rail Freight	320	389	458	458	458	458	458	458	458	458	458	458	458	458	458
Insurance of Fixed Assets	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,125
Business Tax	152	185	218	218	218	2,173	2,173	2,173	2,173	2,173	2,173	2,173	2,173	2,173	2,173
Cost of Products Sold	12,452	14,020	15,182	15,182	14,777	16,732	16,732	16,732	16,732	16,732	16,732	16,732	16,732	16,732	16,732
Income from Operations	9,598	12,755	16,318	16,318	16,723	14,768	14,768	14,768	14,768	14,768	14,768	14,768	14,768	14,768	14,768
Interest on Long Term Debt	5,375	4,972	4,434	3,897	3,359	2,807	2,284	1,747	1,209	672	134	-	-	-	-
Income Before Depreciation	4,223	7,783	11,884	12,421	13,364	11,961	12,484	13,021	13,559	14,096	14,634	14,768	14,768	14,768	14,768
Depreciation	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773
Income Before Tax Allowances	(550)	3,010	7,111	7,648	8,591	7,188	7,711	8,248	8,786	9,323	9,861	9,995	9,995	9,995	9,995
Allowance for Freight, Power, etc.	-	-	-	-	-	-	-	-	5,375	5,375	5,375	5,375	5,375	5,375	5,375
Taxable Income	(550)	3,010	7,111	7,648	8,591	7,188	7,711	8,248	3,411	3,948	4,486	4,620	4,620	4,620	4,620
Corporate Tax	-	-	-	-	-	-	-	-	511	592	673	693	693	1,386	1,386
Net Income	(550)	3,010	7,111	7,648	8,591	7,188	7,711	8,248	8,275	8,731	9,188	9,302	9,302	8,609	8,609
Plus Depreciation	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773	4,773
Gross Cash Flow	4,223	7,783	11,884	12,421	13,364	11,961	12,484	13,021	13,048	13,504	13,961	14,075	14,075	13,382	13,382
Debt Amortization	2,688	5,375	5,375	5,375	5,375	5,375	5,375	5,375	5,375	5,375	2,688	-	-	-	-
Net Cash Flow	1,535	2,408	6,509	7,046	7,989	6,586	7,109	7,646	7,673	8,129	11,273	14,075	14,075	13,382	13,382

Table IX.8.(A)

Estimated Profit and Loss Statement
Kenaf Bleached Paper Pulps
(Explanatory Notes)

Pulp Production

It is assumed that the total pulp production of the mill will be 70% of the designed capacity of 70,000 ADMT/year the first year, 85% the second year, and 100% for the years thereafter for the life of the projection covering 15 years from the start of commercial operations of the mill.

Pulp Price

In the case of the kenaf whole stalk pulp, the sales price has been set to be competitive with the price of imported bleached hardwood sulfate pulp delivered to a paper mill in Thailand in 1975 at world market contract price.

For the kenaf bast ribbon pulp, the sales price has been set at a value which will give an approximately comparable rate of return to the owners of the mill as shown for the kenaf whole stalk pulp.

Sales Revenue

It is estimated that when the mill is producing kenaf ribbon bleached pulp at full designed capacity, the electrolytic plant will produce an excess of 5 MT/day of chlorine which will be sold locally for Equi. US\$350 per MT F.O.B. the pulp mill. This is the current price in Thailand for this chemical.

Cost of Sales

Direct Production Cost

Variable Expenses

These items are proportional to mill output and consist of fibrous raw material, chemicals, and lignite.

Fixed Expenses

These items are a constant, irrespective of pulp production and consist of the power standby charge, salaries,

Table IX.8.(B)

(Explanatory Notes)
(Continued)

wages, and perquisites (including the cost of a foreign technical assistance team for the first 4 operating years), maintenance and operating materials and supplies for mill and townsite, contingencies, and fire insurance on kenaf stored in the mill yard.

Selling Expense

This is assumed to be 2% of the sub-total representing the Direct Production Cost.

Rail Freight

It is estimated that the pulp mill will prepay the freight of Equi. US\$6.54/ADMT on all pulp to Bangkok or equivalent to the cost of delivering the pulp to the consuming paper mills in Thailand.

Insurance of Fixed Assets

The annual premium cost to cover the risks of fire, boiler explosion, and other hazards is estimated to reach 1.5% of the Estimated Total Cost of Fixed Assets that would be insurable. In this case the value of such assets has been taken at Equi. US\$75,000,000.

Business Tax

An allowance on this tax is granted to Promoted Enterprises in the Special Investment Zones in Thailand. The applicable rate after allowances is 0.7% for the first 5 years of operations and 7.0% for the years thereafter. It is applied to the price of the goods sold less the cost of rail freight incurred.

Interest on Long Term Debt

It is assumed that interest on borrowed capital during construction will accrue and will be capitalized as part of the long term debt at the end of the construction period. During operation of the mill an average rate of interest of 10% per year will accrue and be payable on the balance of all outstanding long term debt with payment semi-annually commencing six months after the effective date of beginning of commercial operations of the mill.

Table IX.8.(C)

(Explanatory Notes)
(Continued)

Depreciation

The Straight Line method of depreciation at a rate of 5% per year, applicable to a period of 20 years, has been adopted on the total capital assets involved in site development, plant buildings and structures, and the housing community and facilities. No depreciation is taken on the land purchased. The depreciable assets involved have been estimated at Equi. US\$9,982,000.

The Straight Line method of depreciation at a rate of 6.66% per year applicable to a period of 15 years has been adopted on the total capital required for the total machinery and equipment and "Other Items to Be Capitalized for the Plant," except for spare parts and consumables which are not depreciated. The depreciable capital assets involved amount to Equi. US\$24,500,000.

Allowances for Transportation, and Purchased Water and Electricity

An annual deduction allowed by the Thailand Board of Investment equivalent to double the total cost of transportation of goods and raw materials and double the cost of purchased water and electricity for the mill has been taken prior to corporate tax computations. In this case there is no charge for water. The only charge for purchased electricity is for the power standby charge. This is based on the assumption that the mill will return to the Electricity Generating Authority of Thailand grid any power that is borrowed during emergency and plant shutdown periods.

Corporate Taxes

Maximum exemptions allowed by the Board of Investment of Thailand for Promoted Enterprises in the Special Investment Zones have been adopted. Consequently it is assumed that total exemption from corporate income tax will be allowed during the first 8 years of mill operations and that for an additional 5 years a 50% exemption will apply. The corporate income tax rates adopted are

Table IX.8.(D)

(Explanatory Notes)
(Continued)

those currently applicable as follows:

<u>Amount of Net Earnings</u> <u>(Equivalent US\$)</u>	<u>Tax Rate</u> <u>(%)</u>
0 to 25,000	20
25,001 to 50,000	25
50,001 and greater	30

Amortization of Long Term Debt

It has been anticipated that the amount of long term debt of Equivalent US\$53,750,000 shall be payable in 20 equal semi-annual installments commencing 12 months after the effective date of beginning of commercial operation of the mill.

Indexation

Estimated Profit and Loss Statements for both kenaf whole stalk and bast ribbon pulp projects have been projected on the basis of current cost and price data extended throughout the life of the projection.

Alternative, escalated estimated profit and loss statements have also been made for both types of pulp projects, in which it is assumed that a minimum 3% per annum inflation will affect all goods and services and therefore all costs and prices. Since the high interest rate adopted on long term debt already discounts this eventuality, no similar adjustment is made on debt service commitments, throughout the contract years, until retirement.

Estimated Profitability of a Kenaf
Whole Stalk Bleached Paper Pulp Mill
(Zero Inflation Factor)

Operating Year	Equity Investment Prior to Mill Commercial Operations (Equi. US\$-,000)	Compound Interest Factor	Interest on Equity Before Mill Commercial Operations (Equi. US\$-,000)	Discounted Net Cash Flow (Equi. US\$-,000)
- 4	2,000	1.867 - 1	1,734	
- 3	6,000	1.598 - 1	3,588	
- 2	11,000	1.367 - 1	4,037	
- 1	8,534	1.169 - 1	1,442	
Total	27,534		10,801	- 10,801
	Accumulation of Gross Cash Flow (Equi. US\$-,000)	Annual Net Cash Flow (Equi. US\$-,000)	Discount Factor (16.9%)	
1	4,223	1,535	0.856	1,314
2	12,026	2,408	0.732	1,763
3	23,890	6,509	0.626	4,075
4	36,311	7,046	0.535	3,770
5	49,675	7,989	0.458	3,659
6	61,636	6,586	0.392	2,582
7	74,120	7,109	0.335	2,382
8	87,141*	7,646	0.287	2,194
9		7,673	0.245	1,880
10	*Payback period	8,129	0.210	1,707
11	for US\$81,284	11,273	0.179	2,018
12	is within this	14,075	0.154	2,168
13	year.	14,075	0.131	1,844
14		13,382	0.112	1,499
15		13,382	0.096	1,285
	Value of Working Capital at End of Projection Period	3,227	0.096	310
	Value of Mill at End of Projection Period	40,000	0.096	3,840
	Total of Net Cash Flow, Working Capital, and Value of Mill at End of Projection Period	172,044		
	Equity Value on the Discounted Net Cash Flow Basis for Project at Start of Commercial Operation of the Mill			27,489

Table IX.9.(B)

Estimated Profitability of a Kenaf
Whole Stalk Bleached Paper Pulp Mill
(Zero Inflation Factor)
(Continued)

<u>Calculation of Payback Period</u>	<u>(Equi. US\$-,000)</u>
Total Capital Employed to Establish Project Including Working Capital	81,284
Accumulation of Gross Cash Flow	
End of 7th Year	74,120
End of 8th Year	87,141
Then	
$7 + \frac{(81,284 - 74,120)}{(87,141 - 74,120)} = 7.55 \text{ Years Payback Period}$	
<u>Return on Total Capital Investment</u>	
Total of Net Cash Flow, Working Capital and Value of Mill at End of Projection Period	172,044
Then	
$\frac{172,044 \times 100}{81,284 \times 15} = 14.1\% \text{ Average Annual Return on Capital Investment Over the Projection Period}$	
<u>Return on Equity for the Projection Period</u>	
Equity in the Project	27,534
Then	
$\frac{(172,044 - 27,534) \times 100}{27,534 \times 15} = 35\% \text{ Average Annual Return on Equity Over the Projection Period}$	
<p>By trial calculations with various discount rates and the corresponding values for compound interest, the following has been established for this project for the projection period:</p>	
<p>Annual Return on Equity over the Projection Period on the Discounted Net Cash Flow Basis = 16.9%</p>	

Pulp Price

In establishing the possible selling price for the kenaf whole stalk bleached pulp, consideration was given to the cost data for comparable bleached hardwood pulp imported into Thailand in 1974 as reported to the Department of Customs and shown in Table I.5. in Section 5.3. of Chapter I of this Study. It was calculated from the C.I.F. (cost-insurance-freight) values reported plus the import duty, standard profit tax, business tax, and municipal tax prevailing at the present time together with estimated inland freight and handling charges to the paper mill near Bangkok, that a delivered price of approximately $\text{฿}8,800/\text{ADMT}$ (US\$440.00/ADMT) for the kenaf whole stalk bleached pulp would have been competitive with that for imported bleached hardwood sulfate market pulp in 1974.

Discussion of world market pulp prices at the end of 1975 with international pulp sales companies established a current price level, under long term contracts, of about $\text{฿}9,120/\text{ADMT}$ (US\$456.00/ADMT) for bleached hardwood market pulp delivered to a paper mill near Bangkok. It was projected that the future long term supply of bleached hardwood market sulfate pulp would eventually be on a relatively stable basis when large mixed tropical hardwood sulfate pulp mills under consideration in many areas of the world are implemented.

Based on this information, and for purposes of financial analysis for a kenaf whole stalk bleached pulp mill, projections of profitability have been made based on a price for the pulp delivered to a paper mill at Bangkok of $\text{฿}9,000/\text{ADMT}$ (US\$450.00/ADMT).

For kenaf bast ribbon bleached pulp, it was quite obvious that it would have a higher fibrous raw material cost of $\text{฿}3,213/\text{ADMT}$ (US\$160.65/ADMT) of pulp than kenaf whole stalk pulp. Even when credited with about $\text{฿}200/\text{ADMT}$ (US\$10.00/ADMT) of pulp for excess chlorine produced and sold as well as credits for other savings in bleaching chemicals, a sales price premium of approximately $\text{฿}3,000/\text{ADMT}$ (US\$150.00/ADMT) would result for the kenaf bast ribbon pulp over the price of whole stalk pulp for them to be on approximately the same profit basis. Therefore, it is clear that the bast ribbon pulp mill would have to be based on a sales price of $\text{฿}12,000/\text{ADMT}$ (US\$600.00/ADMT) on a delivered basis, for such a project to be equally commercially profitable in comparison with the whole stalk pulp operation.

Obviously this sales price for kenaf bast ribbon pulp is about $\text{¥}2,600/\text{ADMT}$ (US\$130.00/ADMT) higher than the $\text{¥}9,400/\text{ADMT}$ (US\$470.00/ADMT) of softwood bleached sulfate pulp that international pulp sales companies report would be the delivered price at the paper mill in Thailand at the present time for long term contracts. However, these sales agents state that, in their judgement, the differential between softwood bleached sulfate pulp prices and hardwood bleached sulfate pulp prices will become much greater in the future due to anticipated shortages in supply of softwood pulps on the world market. It is also adduced that the fibrous raw material costs will increase much faster in the industrialized nations, where these softwood pulps are produced for export, than they will for the hardwood pulps produced in the tropical area mills.

It could be considered that special uses for kenaf bast ribbon pulp for the more expensive grades of high strength fine papers such as cigarette paper and air mail bonds might be developed either within the Mekong Basin countries or on the world export market and would adequately justify the price chosen for the financial projection. This would be important but the Consultants do not believe any weight should be given to such possibilities at this point.

Instead, it appears that the benefits to the Mekong Basin countries resulting from the production of kenaf bast ribbon pulps, as compared to the alternative of importing softwood pulps, would be far greater in relation to the national interests. The Thailand Promotion of Investment Law (NEC Announcement No. 227) clearly recognizes this factor in allowing the Board of Investment to offer special tariff protection which would prohibit the importation into Thailand of like products or would increase the duties on like products imported. It has been stated that a further levy of 50 percent of the C.I.F. value can also be imposed on the competitive imports on a year to year basis. Actually, an additional import duty of about 28 percent on softwood pulp above the present 1 percent would be required to compensate for the difference in fibrous raw material cost between kenaf whole stalk and bast ribbon pulps.

Inflation Factor

In the past, most pre-feasibility studies contained financial projections and analyses which were based on the fixed value of the monetary unit over the projection period and with no consideration given to the effect of inflation on the profitability of the project in relation to a fixed amount of debt and interest on it. In this Study, separate projections of estimated profit and loss statements with zero inflation factor have been made for both kenaf whole stalk and bast ribbon pulp mills. Similar projections have also been made

for both pulp mill projects in which escalation of prices and costs has been considered in relation to a fixed debt and interest on it. An average inflation factor of 3 percent per annum was chosen as the minimum that would occur over the projection period. This was done with the realization that the relatively high interest rate of 10 percent for the fixed long term debt that has been used in these calculations has already discounted the escalation factor to some degree.

The Consultants believe that the use of the inflation factor at a conservative 3 percent per annum compounded annually makes the financial feasibility more realistic than where the entire projection period data are based only on costs and prices at the time of the beginning of commercial operation. The use of inflation factors or "indexation" to compensate for escalation of prices and costs during the entire period covered by a financial analysis is becoming more widely used by companies in the United States and, for many years, it has been used as a key economic planning tool in countries which have high inflation rates. It has even been proposed in the United States Congress (219) that the federal tax system and future long term government debt securities be tied to the Consumer Price Index. The necessity for and advantages of considering the inflation factor in long range business planning and project evaluation with various accounting procedures has been discussed by Vancil (220) and he has given some very interesting examples showing the effects of inflation on project financial analyses.

It is not only important to build the inflation factor into the financial projection, it is required as well that the time value of money be considered in a profitability analyses. Table IX.9. gives an example of financial analysis on the Discounted Cash Flow (DCF) basis for the whole stalk kenaf pulp mill project when the inflation factor has not been included. It also shows that the interest value of the equity money put into the project before the start of commercial operation has been given full-time weight and credit in the discounting evaluation.

A summary of the definite titles and calculated values of various profitability estimates for the kenaf pulp mill projects has been given in Table IX.10. for both types of kenaf pulp mill projects, with and without the inflation factor included. The different calculations used to estimate project profitability are:

Estimated Profitability of Kenaf Bleached
Paper Pulp Mills for the Mekong Basin
Area for the Project Projection Period

<u>Item</u>	<u>Type of Kenaf Pulp Produced in Project</u>			
	<u>Whole Stalk</u>		<u>Bast Ribbon</u>	
	<u>(Inflation Factor Used)</u>	<u>(Inflation Factor Used)</u>	<u>(Inflation Factor Used)</u>	<u>(Inflation Factor Used)</u>
	<u>(0%)</u>	<u>(3%)</u>	<u>(0%)</u>	<u>(3%)</u>
Payback Period (Years)	7.55	6.76	7.75	6.9
Average Annual Return on Total Capital Investment (%)	14.1	20.3	13.5	19.3
Average Annual Return on Equity (%)	35.0	53.1	34.6	52.3
Annual Return on Equity on the Discounted Net Cash Flow Basis (%)	16.9	20.4	16.4	19.9

Table IX.10.

Payback Period

This is the number of years that would pass from the time of start of commercial operation of the mill until the accumulated gross cash flow (net income per year after taxes plus depreciation) in the financial projection equals the total capital employed to establish the project, including the working capital. This is a measure of the rapidity with which the total capital investment can be returned and is important for short term projects where liquidity is a prime objective. On the other hand, it does not take into account the number of years beyond payback that earnings will continue nor does it consider the rate at which these inflows occur based on the time value of money. It also does not give any recognition to the value of the mill at any future time. The Consultants do not consider the payback period a proper expression for the profitability of the project mills.

Return on Total Capital Investment

This accounting or average return method over the projection period as used in this Study correctly gives value to the working capital and the plant at the end of the projection period. It does not take into account the timing of money flows and could provide the same average rate of return for projects which have entirely different rates of repayment. This expression of profitability is considered to be of secondary value for the evaluation of these projects.

Return on Equity

The simple expression of average annual return on equity over the projection period gives a very high calculated value that appears to be very favorable for the owners of the enterprise. It is misleading in that it does not give any weight to the years when stepwise equity investments were made over a period of several years prior to the start of commercial operations of the mill even though it does take into account the anticipated monetary value of the mill and the working capital at the end of the projection period.

The Consultants recognize the weaknesses in all the previous expressions of profitability and believe that the most meaningful calculation of profitability for the projects in this Study is the annual return on equity on the Discounted Net Cash Flow (DCF) basis. This takes into account the fact that money received earlier has a greater value than money received later. It also considers the interest on the money put up for equity before the start of operations

and net cash flow that will be at the disposition of the owners of the company after all debt and tax obligations are met. The realistic return on equity is given by this method and is the rate of discounting which equates the sum of the present values of the series of future net cash flows and the values of the working capital and plant at the end of the financial projection period to the present value of the original equity investment and the interest the equity money could have earned at the same rate of compound interest in the period prior to the start-up of commercial operations of the mill. In Table IX.9., the final calculation has been shown whereby the approximate rate of return on equity on this basis of DCF has been established by trial and error calculations using different rates of discounting (and the equivalent rates of compound interest for the original equity investment before start up).

The financial analysis on the DCF basis, without consideration of the inflation factor, shows that the true return on their equity investment to the owners is actually 16.9 percent for the kenaf whole stalk bleached pulp mill. This is when the pulp is sold in Thailand at the competitive price for imported hardwood bleached sulfate pulp. This is also based on the assumption that, at the end of the projection period, the mill will be worth US\$40,000,000 or about half the value of the original total capital investment. Actually, by that time, the rate of inflation for the projection period could very easily make the mill worth even more than the original capital investment in the same unit of money.

As discussed earlier in this chapter, the fibrous raw material cost of the kenaf bast ribbon developed in the agro-economic sections of this Study is so much higher than the cost of the whole stalk that the bast ribbon pulp will have to sell at a delivered price of ¥12,000/ADMT (US\$600.00/ADMT) or ¥3,000/ADMT (US\$150.00/ADMT) of pulp more than the delivered price of ¥9,000/ADMT (US\$450.00/ADMT) for the whole stalk pulp if the projects are to show approximately equivalent profitability over the financial projection period. The data in Table IX.10. take this factor into consideration and are based on the assumption that the required import duty or an embargo against importing softwood pulp would be granted by the Government of Thailand to assure the economic viability of the kenaf pulp mill using bast ribbon.

Consideration has been given to the possibilities for reducing the cost of the kenaf bast ribbon by purchasing the whole stalk material from the farmer and separating the two components at the mill so that the woody core material could be used for fuel, the manufacture

of mechanical pulp to be used for newsprint, particleboard or fiberboard, or chemical products. This has been discussed in detail in Chapter I, Section 4.3. of this Study as a recommendation for further investigation in a feasibility study for this project. However, no consideration has been given to such hypothetical savings in the cost of raw material for kenaf bast ribbon pulp in the financial projections made here.

It should also be noted for the data in Table IX.10. that the return on equity on the DCF basis is higher than the 3 percent inflation factor when that is used. This results from the fact that the initial debt and interest on it are paid in fixed monetary units whereas the costs and prices are escalated as the purchasing power of the monetary unit decreases over the projection period. This indicates that lending agencies for such projects may eventually compensate for this advantage of the equity owners by "indexation" of their loans.

5. The Economic Values of the Various Kenaf Pulp Project Options

When a full feasibility study is made for the kenaf pulp project, an in-depth evaluation will have to be made of the national social and economic benefits which will result to the country where the mill would be located. This analysis would use the methodology discussed in publications pertinent to this subject by FAO (205) and UNIDO (221).

For this Pre-Feasibility Study, the Consultants have summarized the data given in Table IX.11. on the economic values of the various project options which have been discussed in this chapter. It is of interest to outline briefly the benefits that would possibly accrue from establishing the kenaf whole stalk pulp mill, as an example without any consideration of inflation factor.

Employment

The mill would employ in excess of 700 people directly. As a result of these new jobs, there would be an increase of supporting and service jobs in the nearby community for possibly three times this number of persons. In the agricultural area, the production of the fibrous raw material and its harvesting and transport to the mill would provide new employment and steady income for a great number of families. The production of the chemicals and the mining of the lignite for the mill would provide new jobs for a great number of people in other parts of Thailand. Considerable local employment would also be generated in building the mill and the equipment that would not be imported.

Local Expenditures

During the projection period, the pulp mill would average spending about ₪288,280,000 (US\$14,414,000) per year for local goods and services out of a sales revenue of about ₪611,100,000 (US\$30,555,000) per year. There would also be an expenditure for local facilities, services and equipment of ₪486,140,000 (US\$24,307,000) during the construction period for the mill.

Taxes

In addition to the taxes that would be generated as a result of the new business activity associated with the mill, the company would average paying about ₪30,280,000 (US\$1,514,000) in business tax each year on its sale of products. Due to the generous allowances made in the corporate income tax exemptions for a Promoted Enterprise, this tax would average only about ₪7,920,000 (US\$396,000) per year for the

Total Economic Values for the Financial
Projection Period on Various Kenaf Pulp Project Options

	Total Values for Types of Kenaf Pulps Produced in the Projects (Equivalent US\$-,000)			
	Whole Stalk		Bast Ribbon	
	(Inflation Factor Used)		(Inflation Factor Used)	
	(0%)	(3%)	(0%)	(3%)
Sales Revenue	458,325	571,578	620,019	773,184
Local Expenditures for Production of Mill Products	216,212	264,600	372,261	459,199
Business Tax	22,721	29,933	30,852	40,686
Corporate Income Tax	5,934	11,088	4,927	10,321
Interest on Debt	30,890	30,890	31,208	31,214
Debt Repayment	53,750	53,750	56,367	56,367
Net Cash Flow	128,817	181,316	124,403	175,347

entire period and payment of any income tax would actually not begin until the 9th year of the projection period. Counterbalancing part of these taxes paid, however, would be the loss in revenue to the Government of Thailand from duties and other taxes presently applied against the C.I.F. value of an equivalent amount of pulp imported into Thailand. This has been calculated to be about ฿16,840,000 (US\$842,000) each year.

The net cash flow during the projection period would also make additional money available to the stockholders as dividends that would be subject to income tax. Income tax would also be generated by the salaries and wages of the mill employees and all persons supplying goods and services to the mill. These taxes would be of great benefit to the Government because they would replace what had previously been an outflow of foreign exchange from the country.

Foreign Exchange Savings

The long term contract C.I.F. price for hardwood bleached sulfate pulp prevailing in Thailand at the end of 1975 was US\$435.00/ADMT. The average annual production of the proposed kenaf bleached pulp mill for the period of 15 years covered by the financial projections in this Study is 67,900 ADMT/year. Therefore, the foreign exchange disbursement to acquire this total of 1,018,500 ADMT of pulp from foreign producers would represent to Thailand a total of US\$443,048,000 or an annual average of US\$29,537,000 for the projection period.

However, during the first 10 year period of commercial operation of the mill, the service of foreign debt (principal and interest) incurred in financing the kenaf pulp mill will require a total of US\$84,640,000. In addition, the services of the Foreign Technical Assistance Team will require the pay-out of a total of foreign exchange of US\$1,115,000 within the first 4 years of commercial operation of the mill. It is also estimated that, during the financial projection period of 15 years, a total of US\$10,000,000 of foreign exchange will be required for the purchase of spare parts abroad. Hence, it appears that during the projection period a total expenditure of foreign currency on the order of US\$95,755,000 would be required.

Therefore, during the projection period of 15 years, a total of US\$347,293,000 or an annual average of US\$23,153,000 of foreign exchange will have been saved for Thailand if the kenaf pulp mill is established there.

6. The Financial Viability of the Kenaf Pulp Project Options

Based on the information on costs and prices gathered on the field trip for this Study in Thailand and the kenaf pulp mill capital investment and operating costs developed by the Consultants, the resultant analyses show that the kenaf whole stalk bleached pulp mill would be financially viable when selling the product at a price equivalent to that being paid by the paper mills in Thailand at the present time on long term contracts for hardwood bleached sulfate pulp. Assuming equal acceptance of the kenaf whole stalk pulp by the paper mills on a technical basis in comparison with the imported hardwood pulp, there is no indication that any tariff or embargo protection would be required for the mill under the conditions existing at the time of this Study.

There is one possibly serious interfering and competitive factor on the local level in this picture however. It is the probability that a bleached pulp mill project based on bagasse and bamboo might be undertaken before the kenaf project. For some years such a pulp mill has been under development in Thailand and the Board of Investment (140) has listed such a Promoted Pulp Factory under the name of the Thai Pulp Company Ltd. A feasibility study for this mill has been carried out by Sandwell (222) but is not available for comment or review in this report.

This proposed mill is listed as using bagasse and bamboo for fibrous raw materials. Because the cost of bagasse for pulp generally carries only a small premium over its fuel replacement value when used in the generation of steam in the sugar mill boilers, it usually is a very low cost and therefore economically advantageous fibrous raw material for pulp. In Section 4.2. of Chapter I of this Study it was estimated that, if lignite were the replacement fuel, the bagasse pulp could sell for approximately $\text{฿}852/\text{ADMT}$ (US\$42.60/ADMT) of bleached pulp product lower than kenaf whole stalk pulp and still produce an equivalent financial viability for the pulp mill. Even if oil had to replace the bagasse at the sugar mill, the bagasse pulp would still have the advantage of a lower cost by $\text{฿}208/\text{ADMT}$ (US\$10.40/ADMT) even though the kenaf pulp mill used lignite for its fuel. These calculations and comments, of course, are based on the assumption that there would be equal acceptability for bagasse and kenaf whole stalk pulps as substitutes for the imported hardwood sulfate market pulp. This differential between the cost of bagasse and kenaf whole stalk fibrous raw material would allow the use of some bamboo, even if it has a higher cost per ton of pulp product than bagasse or kenaf whole stalk, as an additive to upgrade the strength properties of the bagasse pulp and to make it suitable for use in higher percentages in most grades

of paper where some softwood sulfate pulp is required to raise the tearing strength of the paper to acceptable levels.

Therefore, these technical and economic factors relating to possible market competition from the proposed bagasse bamboo pulp mill in Thailand will have to be kept in mind when further consideration is given to the kenaf paper pulp mill. However, it will also have to be considered that the kenaf pulp mill would furnish far more employment in the agricultural sector to produce its raw material than would a pulp mill based primarily on bagasse which could be used for fuel anyway. Also the important factor that must not be overlooked is that kenaf is the major papermaking fiber available in the Mekong Basin area and its production for pulp would be in the interests of the riparian countries for stabilizing the market for this labor intensive raw material in that area.

In the case of the kenaf bast ribbon pulp, the cost of the fibrous raw material is so much higher than for the kenaf whole stalk pulp that equivalent financial viability for the project for bast ribbon pulp would require about a 33 percent higher sales price as noted earlier. As the kenaf bast ribbon pulp would be produced only as needed and as a substitute for softwood sulfate pulp, this presently imported pulp would have to carry about a 28 percent import duty to make its price competitive with the bast ribbon pulp. Otherwise, the local product would have to be protected to the extent of required production of this grade for the local market by an embargo on softwood pulp imports.

Beyond this analysis of the situation, the Consultants judge that kenaf bast ribbon pulp in this case does not appear to be as attractive a product option, even though it is an alternative carrying considerable national benefits in its own rights, as the kenaf whole stalk paper pulp would be. Fortunately, for a kenaf pulp mill all options really remain open as long as there is a sufficient market for the pulp to keep the mill operating at full rate. It is only necessary to plan and design the facilities of the pulp mill to use the kenaf whole stalk in such a way that merely by shifting fibrous raw material the bast ribbon pulp could be produced.

CHAPTER X. - DEVELOPMENTAL ACTIVITY REQUIREMENTS

1. Introduction

This Chapter X will discuss the further investigative, research, pilot program and other developmental activities which, in the opinion of the Consultants, should be undertaken prior to a decision being made with respect to the implementation of one or more kenaf pulp mill projects in the Lower Mekong Basin, as discussed in this Pre-Feasibility Study. As will be seen, the suggested scope of such future activities is rather comprehensive and that in view of the fact that, so far, very little "commercial" type work has been carried out both with regard to kenaf for paper pulp field production and the conversion of kenaf into pulp and paper.

As in the foregoing chapters of this Study, the agro-economic and mill conversion project aspects will be discussed separately hereunder. These discussions will form the basis for the formulation of Draft Terms of Reference for the further development of a Kenaf for Paper Pulp Program in the Lower Mekong Basin.

2. Agro-Economic Aspects

2.1. Agronomic Considerations

2.1.1. Kenaf Variety Selection

One of the basic concerns of any future kenaf for paper pulp development program in the riparian countries must be the selection of both H. sabdariffa and H. cannabinus varieties with a view to achieving maximum yields of whole stalks and bast ribbon for subsequent pulping and conversion into paper. Although such variety selection will largely duplicate that aimed at improved retted fiber production for conversion into such end-products as hessian, burlap and bags, additional consideration will have to be given to any potential differences in pulping qualities of the various varieties.

Variety selection will have to include testing of both the locally available and of newly introduced varieties. As already described in this Study, particularly in Chapter II, a considerable amount of kenaf variety selection work has already been carried out in the riparian countries and it is by no means suggested that such work should be duplicated under the kenaf for paper pulp development program. Rather, the program should take full advantage of the results already achieved but should repeat those trials which have provided contradictory results and further expand others, with particular emphasis on desirable varieties for paper pulp rather than for textile fiber production.

Furthermore, the program should aim at carrying out its variety trials in or as close as possible to the areas within economic kenaf raw material supply distance to the pre-selected potential pulp mill sites and on the different soil types of such areas.

With regard to H. sabdariffa, the varieties tested should include THS-22, THS-24 and THS-30 which have done exceptionally well in past trials in Viet-Nam, as well as improved selection of the standard Thai Green and Thai Red varieties. Attention must also be paid to resistance to phytophthora disease which has already become prevalent in several kenaf production areas in Northeast Thailand and which substantially reduces yields. Past trials at the Nong Soon Fiber Crops Research Station north of Nakorn Ratchasima and at the Regional

Agricultural Research Center at Tha Phra near Khon Kaen, both in Northeast Thailand, have confirmed the exceptional qualities of THS-30 as well as of the additional THS-40 variety. Varietal selection (and other kenaf research work) is continuing at both these centers and is to be intensified under a recently finalized general seed improvement program in Northeast Thailand supported by the World Bank. At this time, it appears that any trials in potential kenaf for paper pulp supply areas should concentrate on the following H. sabdariffa varieties:

THS-22; THS-24; THS-30; THS-40;
Thai Green; Thai Red.

As to H. cannabinus, varietal selection trials for kenaf for paper pulp will have to concentrate on the "standard" varieties of this species as follows:

Cuba 2032; Guatemala 4, 45 and 51;
Everglades 41 and 71.

Amongst these varieties, the Guatemalan selections are less photo-sensitive and can, therefore, be planted later in the season (or closer to the Equator). The Everglades varieties, on the other hand, are partly nematode resistant which permits their planting in lighter soils.

2.1.2. Land Preparation

As discussed in Chapter III, the land in the kenaf producing areas in Northeast Thailand is only shallow plowed and raked with animal drawn wooden implements. Whilst this is adequate for the sandy soils in that area, this may not be so for some of the heavier soils to be reserved for the H. cannabinus species (see the Mekong Basin Soil Map, Plate IV.1.). In addition, this latter species requires extra care in land preparation if the crop is not to be damaged by weeds. Hence, limited research into minimal land preparation requirements should be carried out, particularly with a view to developing specific recommendations for new H. cannabinus farmers, such as in the southern tier of Northeast Thailand and in parts of Laos, Cambodia and Viet-Nam.

2.1.3. Planting

Under this heading, two aspects will have to be investigated, namely planting periods and planting methods.

2.1.3.1. Planting Periods

Generally, kenaf should be planted as early as possible in the season in order to allow for a maximum growth period before it flowers at which time the vegetative development of most varieties is arrested. Since, on the other hand, moisture is required for seed germination, the start of the planting season is determined by the start of the rainy season which falls into the April/May period in the Lower Mekong Basin area. In this Study, May 15 has been assumed to be the average kenaf planting date. Seed planting should be completed not later than June 30.

The above does not apply to the photo-insensitive H. cannabinus varieties, e.g. Guatemala 4, 45 and 51 which, theoretically, can be planted at any time of the year (within the limitations imposed by rainfall or irrigation water availability) and, again theoretically, will flower about 120 days after planting; also, their vegetative development after flowering will continue.

Little is known about the photo-sensitivity of the "THS" varieties of H. sabdariffa some of which are said to have been introduced from Indonesia. If that is indeed the case, they should be reasonably photo-insensitive, since they have then been selected at the Industrial Crops Research Institute at Bogor which is situated only some 5 degrees south of the Equator.

Future planting period investigations, again in the potential kenaf for paper pulp supply areas, would then have to emphasize the following:

- Latest permissible planting dates of H. sabdariffa;
- Photoperiod response of the THS varieties of H. sabdariffa and possible staggered planting potential of these varieties;
- Photoperiod response of the H. cannabinus varieties;
- Staggered planting of the photo-insensitive H. cannabinus varieties.

2.1.3.2. Planting Methods

This Study has shown that there exists a wide divergence between the kenaf planting systems adopted in different production areas, both with regard to planting methods and seed spacing.

Basically, and as discussed in detail in Chapter V, Section 2.3.2., H. sabdariffa has to be planted at sufficient distance between the seedlings to permit weeding and thinning, whereas H. cannabinus can be planted closer since the shading effect of its leaves and its more rapid seedling development makes these operations unnecessary.

For both varieties, row planting should definitely be adopted since it increases yields substantially; standard inter-row spacing should then be 30 cm. for H. sabdariffa and 17 to 20 cm. for H. cannabinus. However, if standard type forage harvesters are to be used for stalk cutting and chopping, these inter-row spacings may not be feasible and a thorough investigation of this aspect is required.

The above two "standard" inter-row spacings are those traditionally adopted in kenaf retted (textile) fiber production, the 30 cm. spacing for H. sabdariffa by the small holder kenaf (and jute) producers in South Asia and the 17 to 20 cm. spacing for H. cannabinus by small holders in Africa and on commercial plantations in Africa and Latin America. No specific trials have as yet been carried out in the developing countries as to whether the same spacing will indeed result in optimum kenaf for paper pulp yields. Such trials have been undertaken in the United States but that under soil and climatic conditions differing greatly from those in the Lower Mekong Basin; much more limited trials in other countries were by no means conclusive.

The problem of inter-row and in-the-row spacing, in turn, raises the question of seed requirements. A figure of 25 kg./ha. of H. cannabinus seed is universally accepted in the developing countries, but the U.S. Department of Agriculture proposes precision seeding at the rate of some 7 to 9 kg./ha. Although such precision seeding is hardly feasible for small holders, it deserves further investigation as far as, say, the Demonstration Farm is concerned.

There is some difference of opinion as to seed requirements for H. sabdariffa plantings at the recommended 30 cm. inter-row distance. In Thailand, the accepted seed planting rate is 2 kg./rai equivalent to 12½ kg./ha.; in the trials in Viet-Nam, 18 kg./ha. are said to have been used.

With regard to actual planting methods, there is again ample scope for improvement. Assuming acceptance of the recommendation of row planting rather than broadcast planting, the major alternatives are:

- Furrow opening with a stick along a string drawn between two pegs;
- Opening several furrows simultaneously by means of a hand pulled seeding rake;
- Opening several furrows simultaneously by means of a draft animal pulled seeding rake;
(Note: Under each of the above three alternatives, the seed would then be dibbled by hand into the open furrows)
- Planting with a hand pushed single row seed drill;
- Planting with a draft animal pulled multi-row seed drill;
- Planting with a tractor pulled multi-row (15 to 21 rows) seed drill.

For each of the above alternatives, tests should establish the exact methodology and implement adjustment, planting area per man-day and work shift, seed requirements, and planting costs.

2.1.4. Fertilization

Fertilizer trials should, obviously, be carried out in each of the potential kenaf for paper pulp production areas and fertilizer requirements and recommendations will vary according to the soil fertility conditions in those areas.

It has been stated that H. sabdariffa in Northeast Thailand shows only a minimum response to fertilizer application. The Consultants feel that this may be a too generalized statement and that it may well apply only to the two local unimproved varieties, Thai Green and Thai Red. Thus, the H. sabdariffa varieties selected in Indonesia show a very positive response to fertilizer, both in research trials and in actual field production, and introduced Indonesian varieties should certainly be included in the fertilizer trials.

There is also marked disagreement between the fertilizer recommendations for H. sabdariffa of the Thai Ministry of Agriculture and those resulting from the previous trials in Viet-Nam. Similarly, the H. cannabinus fertilizer recommendations based upon the Viet-Nam trials differ substantially from those generally accepted in kenaf producing areas elsewhere in the developing countries.

As part of the proposed future trials, test should also be carried out with respect to fertilizer application methods, including both manner and timing of such applications. These tests should include hand dibbling, the use of hand pushed single row and draft animal or tractor drawn multi-row seed drills, and pre-planting, at-time-of-planting, and subsequent-to-planting single and split applications, as well as side and top dressings.

2.1.5. Cultural Methods

Under this heading are included weeding and thinning, and pest and disease control. Practices for these cultural operations are well established and described in detail in this Study. Weeding and thinning operations, for H. sabdariffa only, will be carried out within the framework of the overall trial program, and the pest and disease control measures described in Chapter V, Section 2.6., should be confirmed.

Particular attention should be paid to the rootknot nematode problem which is particularly serious for H. cannabinus planted on the lighter soils, and the necessary guidelines for the assistance of the growers in the Lower Mekong Basin should be developed.

2.1.6. Seed Production

The production of improved seed for distribution to the kenaf for paper pulp growers will be a major task in view of the large kenaf areas required to satisfy the raw material needs of the project pulp mill(s), and the trial program will have to place particular emphasis on the development of optimum production methods, where the normal developmental/production sequence of breeder seed-foundation seed-extension seed will most likely be adopted. Included in the seed production trials will have to be those varieties already recommended for the variety testing program.

A wide range of figures is cited for seed yields for both H. sabdariffa and H. cannabinus. However, there have been only very limited commercial (as opposed to research) seed production programs in the past in the Lower Mekong Basin even for H. sabdariffa and none at all for H. cannabinus. In view, again, of the very large seed requirements for kenaf for paper pulp production even for a single project mill - of the order of 350 to 1,200 tons annually for a 70,000 ADMT kenaf whole stalk and bast ribbon pulp mill respectively - the establishment of seed yields and seed production costs deserves every attention.

2.1.7. Rotation Crops and Soil Conservation

At various times in the foregoing Study, groundnuts, paddy, mung beans, green manures, pulses and sunn hemp have been suggested as suitable rotation crops for kenaf, and the almost complete absence of any efforts at soil conservation on the kenaf farms has been emphasized.

Although investigations into rotation crops and soil conservation measures might well be considered beyond the scope of a developmental program for kenaf for paper pulp production, they are mentioned here since they could well be incorporated into such a program in the normal course of work concerned with other trial program aspects.

2.1.8. Production Area Selection

The question of actual and potential kenaf for paper pulp production areas has been discussed in detail in Chapter IV of this Study. As part of the required developmental activities, this question will have to be investigated in much greater depth than has been possible within the framework of this preliminary Study and, once a more definite determination has been made, the entire trial program discussed in this Chapter X should be sited accordingly.

2.2. Crop Harvesting, Processing and Handling

2.2.1. Harvesting

2.2.1.1. Harvesting Periods

For kenaf whole stalk and chopped stalk production for paper pulp there is, theoretically, said to be considerable latitude as to harvesting periods since the stalks can be cut at any time after maturity, i.e. at the time of flowering and at any time thereafter until the land is required for the next following crop. However, these assertions have not yet been confirmed in practice outside of the U.S.A. where soil and climatic conditions differ greatly from those in the developing countries in general and in the Lower Mekong Basin in particular. Hence, time-of-harvest trials for kenaf whole stalk and chopped stalk production are of primary importance. These will be inter-related with the field drying and raw material baling trials discussed below.

For ribbon production, the optimum harvesting period will be much more restricted and limited to the period between flowering and the drying out of the stalk, a time span of approximately 30 to 45 days.

Another factor affecting the time of harvest is the photo-sensitivity of the kenaf variety being grown. As discussed already in this Chapter X, a number of H. cannabinus varieties with different photoperiod response have been developed and these can be planted at different dates and, in turn, harvested at similarly staggered dates. Although it is generally assumed that less photo-sensitive varieties of H. sabdariffa are not available, the Consultants feel that trials will show that the varieties developed in Indonesia, close to the Equator, are indeed less photo-sensitive although, as experience in Indonesia has shown, more photo-sensitive than the H. cannabinus varieties selected for lesser photoperiod response.

Thus, the time-of-harvest trials will have to take into consideration not only the optimum harvest time for maximum yield, but also such factors as the time of planting, the type of kenaf pulping raw material being produced, and the subsequent processing, if any, and handling of the raw material before it is delivered to the pulp mill yard gate.

2.2.1.2. Harvesting Methods

Under any kenaf for paper pulp program, the harvesting methods employed will have to take into consideration the type of kenaf raw material required.

For small holder operations, whole stalk harvesting will consist of the cutting of the stalks at ground level, the cutting off of the stalk tips (topping), and the shocking of the stalks for field drying. For chopped stalk production, the stalks will then have to be cut into the desired length chips, either by the small holders, in a central chopping plant most likely located at one of the baling centers, or by means of mobile field choppers. For ribbon production, the stalks will again have to be cut at ground level and topped, but the bast ribbon must then be stripped off by the small holders as soon as possible and not later than 48 hours after harvesting. One of the tasks of the trial program must be the establishment of the quantity of end-product produced per man-day in each of the above operations.

For larger operations, such as on the proposed Demonstration Farm(s), whole stalks would be harvested by high-crop harvester, chopped stalk material would be produced by forage harvester and, possibly, by means of a modified sugar cane harvester, and for ribbon production, the stalks would again be harvested by high-crop harvester and would then be stripped in mobile field ribboning machines. For each of the foregoing alternatives, the trial program will have to establish outputs, manpower requirements, and operating and production costs.

2.2.2. Stalk and Ribbon Yields

2.2.2.1. Stalk Yields

This is a subject which has been investigated in depth in the U.S.A. and, to a limited extent, in Australia and one or two developing countries. However, soil and climatic conditions in the U.S.A. and Australia differ drastically from those in the major kenaf production areas and the few developing country tests, including the one in Northeast Thailand cited in Chapter V, Section 3.2.1., of this Study,

were much too superficial to furnish reliable results. Since stalk yields are of little interest as far as the long-established kenaf retted (textile) fiber production is concerned, such yields have, in the past, only been investigated in a general way in order to establish indicative ranges of retted fiber yield percentages.

Thorough research into stalk yields of both H. sabdariffa and H. cannabinus for paper pulp production is absolutely essential, where such research must take into consideration variations in soil and climatic conditions, seed varieties, planting and harvesting dates, stalk handling after harvest, etc. As has been discussed in Chapter VIII, Section 2.1., even limited increases in stalk yields per unit area would substantially reduce the whole stalk and chopped stalk kenaf raw material costs to the pulp mill.

2.2.2.2. Ribbon Yields and Stalk Composition

Whereas the Consultants have to rely on outside sources of information as far as whole stalk yields are concerned, they are thoroughly familiar with ribbon yields, since ribbon production is an intermediate step of retted fiber production in mechanized kenaf operations. The research program must, obviously, aim at maximizing ribbon yields.

In this connection, it is emphasized that, as pointed out on various occasions in this Study, the stalk and ribbon yields cited herein do not confirm the extensive U.S. Department of Agriculture test results as to kenaf stalk composition, where the USDA arrives at a 60:40 core to bast ribbon ratio, by weight, but where the ribbon yield figures used in this Study represent only 24 percent of the whole stalk weights.

The clarification of these points of divergence between the results obtained by the USDA kenaf for paper pulp research program and the practical experience of the Consultants with kenaf bast ribbon production in all parts of the developing world must be a principal task of the developmental program.

2.2.3. Field Drying and Storage

Here again, the research program will have to concern itself with the different problems raised as a result of the different types of raw material to be produced.

Drying prior to transport of the whole stalks should present the least difficulties since the stalks will already be sufficiently dry at harvest time, if they are cut at the over-mature stage and after the end of the rainy season, or they can readily be dried by assembling them in shocks in the field. With regard to whole stalk storage in the production zone, this can consist of either open-air storage of the field bundles or under-roof storage of press baled stalks or a combination of these methods. The trial program will have to investigate and establish the most efficient and economic approach under local conditions.

For chopped stalk production, optimum field drying and handling methods will have to be developed almost in their entirety for the Lower Mekong Basin area since no relevant previous local experience exists. Important considerations will have to be the time-of-harvest and its influence on the moisture content of the stalk chips, the techno-economic feasibility of drying stalk chips produced from green harvested stalks, and field to baling plant transport and baling plant storage of stalk chips prior to press baling.

For bast ribbon production, the well established field drying, field baling and baling plant storage methods used for retted fiber production will, most likely, prove equally suitable for bast ribbon for conversion into paper pulp, where the developmental investigations would concern themselves with the confirmation of the techniques and costs of these known procedures under Mekong Basin conditions.

2.2.4. Baling

2.2.4.1. Whole Stalks

No practical experience at all exists with regard to kenaf whole stalk baling anywhere; such stalks have simply not been baled in the past, although they have been field bundled for transport to the retting facilities.

In this Study, various assumptions have been made as to the most efficient methods of stalk bundling and baling and these will have to be confirmed or improved upon under the trial program. Similarly, assumptions have been made as to bulk densities achievable, e.g. 44 kg./cu.m. for loose stalk bundles, 100 to 120 kg./cu.m. for field bundled whole stalks, and 300 to 400 kg./cu.m. for press baled whole stalks. These figures are, at best, informed guesses and must be confirmed as must the man-day and baling press outputs and costs.

2.2.4.2. Chopped Stalks

Again, certain assumptions have been made in this Study as to suitable press baling methods, including the assumption that a high-density stalk chip bale will not disintegrate during subsequent handling and transport. Informed guesses have also been made as to bulk densities (72 kg./cu.m. for stalk chips in bulk, 427 kg./cu.m. for press-baled stalk chips). All of these assumptions will have to be confirmed or modified.

A further question to be investigated in connection with chopped stalk baling is the permissible and/or readily achievable moisture content of the chips and the influence of chip moisture on the baling technique and the resistance to handling damage of the resulting bale, with due consideration to the fact that the material will deteriorate in the bale if the moisture content is excessive.

2.2.4.3. Bast Ribbon

Although kenaf bast ribbon for subsequent conversion into retted fiber has been widely produced for many years, it has never been high-density baled as envisaged in this Study, since the retting facilities usually are within reasonable distance from the ribbon production area, nor has much attention been paid to the bulk density of the field boxed ribbons that are normally being transported; field drums are, of course, peculiar to South Asia. Hence, once again, such assumed bulk densities as 140 kg./cu.m. for field boxed ribbon and 576 kg./cu.m. for press-baled ribbon are only approximations and must be further investigated, as must the baling techniques and costs under riparian country conditions.

2.2.5. Transport

Detailed investigations as to transport methods and costs between the raw material collection centers and the pulp mill yard gate are certainly required. Although the trucking rates cited in this Study are probably reasonably correct, since they are based on those applicable to retted kenaf fiber, rice straw, Burma grass, etc., they will of course vary with the bulk density of the whole stalks, stalk chips and bast ribbon to be carried as well as with the manageability of the load.

One assumption made in this Study which must be confirmed is the readiness of the balers and traders located farther away from the mill site to absorb the transportation cost differential, as they are used to doing with other commodities, as this could result in a very substantial raw material cost saving to the mill.

2.3. Agro-Economic Development Program Implementation and Evaluation

It is suggested that the agro-economic investigations listed above and considered essential prior to the implementation of a large-scale kenaf for paper pulp production project could best be carried out within the framework of a combined research and pilot program, where it would be by no means intended to duplicate the kenaf agronomy research efforts of the concerned Government agencies in the riparian countries but rather to support such efforts and to emphasize the specific kenaf for paper pulp aspects.

Whilst such a limited and specialized research program is an essential component of the required developmental activities, it should be supplemented by a pilot program aimed at providing "commercial" results and which might be organized along the lines of the Demonstration Farm discussed in Chapter V, Section 7., of this Study.

It is here pointed out again that even minor improvements achieved by the research and pilot programs, such as slight increases in yields per unit area and/or reductions in harvesting and handling costs, would lead to hundreds of dollars in raw material cost savings per year to the pulp mill in view of its very large volume requirements, and it is felt that, in view of such large potential economies, the pulp mill project would be well advised to provide the necessary financing for the research and pilot programs.

2.3.1. Research Program Implementation

The research trials would concern themselves with the following aspects of kenaf for paper pulp production and processing:

- Variety Trials
- Time-of-Planting Trials
- Fertilizer Trials
- Pest and Disease Control
- Time-of-Harvest Trials
- Stalk and Bast Ribbon Yield Analyses
- Rotation Crops and Soil Conservation

The research effort should be closely coordinated with the Governmental kenaf research program in the host country and, in fact, support and supplement such program. Physically, the kenaf for paper pulp research might be carried out either at an existing Governmental (kenaf) research station or it could form part of the pilot Demonstration Farm. It should also not be forgotten that subsidiary research trials must be carried out in each of the potential kenaf for paper pulp production areas where soil and climatic conditions vary from those at the central research farm.

2.3.2. Pilot Program Implementation

The pilot program - as differentiated from the research program - is intended to furnish production-type results, both from the agronomic and the economic points of view. The Consultants have found in the past that a minimum planting area of some 80 ha. (200 acres, 500 rai) is adequate for that purpose and permits reasonably large individual plantings of the different seed varieties at the different suggested times as well as commercial size harvests as opposed to research plot plantings. Again, pilot plantings - although not necessarily in the 80 ha. range - would be required in each of the major projected kenaf for paper pulp production areas.

Under the pilot program, investigations into the following kenaf production aspects would be carried out:

- Land Preparation
- Planting (periods, methods)
- Fertilization
- Harvesting (periods, methods)
- Field Drying
- Field Storage
- Bundling/Baling

- Seed Production and Processing
- Equipment Operating Schedules
- Labor Requirements
- Operating Costs

The pilot program would also concern itself with such "outside" questions as transportation methods and costs, inter-agency liaison, etc..

2.3.3. Development Program Evaluation

Upon completion of the first year's research and pilot programs, both programs would be reported on in detail and evaluated. In the case of the research program, such evaluation would be complemented by recommendations for future research programming. The technoeconomic evaluation of the pilot program would conclude with recommendations for future large-scale production development.

The project would then be ready for commercial implementation.

2.4. Draft Terms of Reference, Additional Development Program

Based upon the foregoing discussion of the requirements for further investigative activities, and that within the framework of a combined research and pilot program, the following Draft Terms of Reference for an Additional Development Program with respect to the agro-economic aspects of the kenaf for paper pulp project are submitted.

Research Program

- Variety Trials:

Local and introduced H. sabdariffa and H. cannabinus varieties;

Development of phytophthora resistant varieties.

- Time-of-Planting Trials:

Planting periods for H. sabdariffa and H. cannabinus;

Photoperiod response investigations for both H. sabdariffa and H. cannabinus under local conditions.

- Spacing Trials:

The influence of in-the-row and inter-row spacing on whole stalk and bast ribbon yields;

Seed requirements at various planting distances.

- Fertilizer Trials:

Responses to various levels of N-P-K fertilizers on various soils;

Responses to various types of fertilizer application, i.e. pre-planting, at-time-of-planting, subsequent-to-planting, single, split.

- Cultural Practices:

Weeding - methods, timing;

Thinning - methods, timing;

Pest and disease control.

- Seed Production:

Breeder seed, foundation seed, extension seed;

Bulking of improved seed varieties;

Seed yield evaluations.

- Rotation Crop Trials

- Production Area Selection:

Detail survey of potential kenaf for paper pulp production areas within economic transportation distance of the projected pulp mill sites.

- Time-of-Harvesting Trials:

H. sabdariffa for whole/chopped stalk and bast ribbon production;

H. cannabinus for whole/chopped stalk and bast ribbon production;

Influence of harvest period on stalk/bast ribbon and pulp yield.

- Stalk and Ribbon Yields:

H. sabdariffa and H. cannabinus stalk and bast ribbon yield analyses as affected by the above variables and practices;

Stalk composition analyses.

- Research Program Evaluation:

Program evaluation and recommendations for future research programming.

Pilot Program

- Kenaf Varieties:

Pilot planting of proven local and introduced H. sabdariffa and H. cannabinus varieties.

- Land Preparation:

Traditional, improved traditional and limited mechanized methods for small holders;

Fully mechanized Demonstration Farm methods and scheduling.

- Planting:

Staggered planting of the less photo-sensitive varieties;

· Planting Methods:

Small holders - by hand, with seeding rake, with hand pushed single row seed drill, with animal drawn multi-row seed drill;

Mechanized - with multi-row tractor pulled seed drill with fertilizer box.

Planting Distances:

H. sabdariffa and H. cannabinus;

Relationship between inter-row planting distances and weeding and thinning requirements for H. cannabinus;

Seed Requirements:

At various plant spacings and with various planting methods.

- Fertilization:

Limited pilot scale fertilizer response testing using major accepted fertilization rates only;

Pilot scale fertilizer application method testing, incl. use of various types of hand pushed and animal and tractor drawn seed drills.

- Cultural Practices:

Weeding - manual, mechanized;

Thinning;

Pest and disease control measure application.

- Seed Production:

Pilot scale seed planting of the major accepted varieties;

Seed harvesting periods and methods;

Seed processing - manual, mechanized;

Seed storage and viability preservation.

- Soil Conservation Practices

- Harvesting:

Pilot scale time-of-harvesting tests for whole stalk, chopped stalk and bast ribbon production;

Small holder stalk harvesting methods;

Small holder stalk chopping;

Stalk chopping by mobile chippers;

Centralized stalk chopping (in cooperation with baling plants);

Small holder bast ribboning;

Mechanized whole stalk harvesting by high-crop harvester;

Mechanized chopped stalk harvesting by forage harvester;

Machine ribboning of kenaf stalks.

- Field Drying and Storage:

Stalk drying resulting from over-maturity;

Stalk drying through shocking in the field;

Drying of stalk chips;

Drying of bast ribbon;

Whole stalk, chopped stalk and bast ribbon storage in the production zone (in cooperation with baling plants).

- Baling:

(Note: All baling trials to include determination of bulk density range)

Whole stalk field bundling;

Whole stalk press baling (in cooperation with baling plants);

Stalk chip volume, bulk shipment;

Stalk chip press baling (in cooperation with baling plants);

Bast ribbon field drum baling;

Bast ribbon field box baling;

Bast ribbon press baling (in cooperation with baling plants).

- Transport:

Transportation methods, truck capacities, transit times, and transportation costs (in cooperation with baling plants and trucking companies)(all kenaf raw material types).

- Economic Aspects:

Man-day and machine outputs, manpower and equipment requirements, and capital and operating costs for small holder and plantation type whole stalk, chopped stalk and bast ribbon for paper pulp production.

- Pilot Program Evaluation:

Techno-economic evaluation of the pilot program and recommendations for future large-scale kenaf for paper pulp production development.

3. Pulp and Paper Manufacturing Aspects of Near Term Developmental Activity Requirements

3.1. The Value of Further Laboratory Studies on the Pulping of Kenaf

Before the review and analysis of information were made for this Study, the great quantity of available knowledge on the results of the many laboratory and pilot plant trials that have been made on the pulping of kenaf had not been organized in suitable form so that its full meaning and technical worth could be evaluated. Many industrial, educational, and Governmental laboratories have independently studied the pulping of kenaf with the result that there has been much repetition and duplication of efforts. In addition, in only a very few instances have the laboratory bench research results even been applied to pilot plant runs and even much less so to full-scale mill trials. This is unfortunate because the development work on kenaf for paper pulp has covered about a 25 year period without resulting in a completely integrated mill with recovery system being built specifically to run this kind of pulp of either the whole stalk or bast ribbon types. The few papermaking operations which have demonstrated the properties of kenaf pulps on anywhere near a commercial basis are the cigarette paper mill of Tvornica Papira in Yugoslavia using bast ribbon, and for whole stalk kenaf pulp, the FaBoCart mill in Italy, the Eastern Paper Mills Corp. in Sri Lanka, the runs by ASRCT at the Bang Pa-In mill in Thailand, the tests by Ballarpur Paper & Straw Board Mills Ltd. in India, the studies by Oji Paper Co. in Japan, and the various trials in the United States by Eastman Kodak Co., the Herty Foundation, the Hudson Pulp and Paper Corp., and the U.S. Dept. of Agriculture's Northern Regional Research Laboratory. Of these, only the mill in Yugoslavia producing cigarette paper appears to have developed into a continuous commercial operation based on kenaf pulp.

In reviewing the data from the many reports on kenaf pulping that have been covered in Section 2.6. of Chapter I of this Study, and extracting their meaning and correlating the results of all the major investigations, the Consultants arrived at the conclusion that so much careful research has been done over a wide range of conditions that further laboratory pulping trials would add very little to existing knowledge or speed

the commercial pulping of kenaf. The parameters covering the optimum conditions for pulping and bleaching nonwood plant fibers have been developed in the pulp industry for many years and they can be applied, with only slight modifications, directly for the production of kenaf full chemical pulps of both types in commercial quantities.

3.2. The Need for Production of Commercial Quantities of Kenaf Pulps for Market Trials

It is believed that study of this review will indicate to all the researchers on kenaf pulping that the time has now come to proceed from the laboratory studies that have been made directly to pilot plant and semi-commercial trials using modern technology and equipment for pulping and bleaching commercial test quantities of these pulps. They would be produced specifically for market trials making as many grades of paper as possible. This would include both whole stalk and bast ribbon chemical pulps in bleached and unbleached grades so that the complete range of substitution tests in comparison with hardwood and softwood pulps could at least be made in Thailand, the primary potential market. Other countries interested in kenaf and where commercial papermaking trials could be made, could also be furnished reasonable quantities for a definite determination of the suitability of these pulps in their operations. The findings from this broad range of investigations, particularly if runs can be made with kenaf pulps either 100 percent or as the major part of the papermaking fibrous furnish, will be far more meaningful than the limited trials that have been made. Actually, only a few grades such as printing and writing papers have been made and in these tests and the properties of other types of pulps as major fiber constituents have overshadowed the papermaking characteristics of the kenaf pulps.

It is estimated by the Consultants that, with sufficient financing and proper planning and supervision of a program to go directly to the production of commercial quantities of kenaf pulps, the desired results could be obtained within a much shorter period of time than will be required for the developmental agricultural studies outlined in the preceding agro-economic section of this chapter.

3.3. The Problems Relating to Pulp/Paper Manufacturing Remaining to be Solved Before Building a Pulp Mill Using Kenaf

The only problem remaining in the area of fiber raw material preparation that would have to be solved for kenaf on a full-scale basis would be the bale breaking, chopping, and/or fiberizing of both whole stalks and bast ribbon to prepare them for the wet cleaning system. It is believed that there are several designs of equipment already developed and being used to prepare cane for the sugar mills that would be satisfactory for kenaf fiber preparation. Pilot plants at the laboratories of equipment manufacturers could be used for preliminary evaluation and the most satisfactory unit could then be installed and tested full scale on kenaf at an existing bagasse pulp mill which has the proper fiber wet cleaning system and horizontal tube continuous digester for nonwood plant fiber pulping.

By using an existing mill that already has most of the processing equipment that would be required in a kenaf pulp mill, it would be possible, within a very short time, to establish the validity of the parameters of chemical requirements and conditions for pulping and bleaching that have been developed in this Study as a result of coordinating the published data which have been reviewed. Any technical and operating problems that have not been foreseen in this pre-feasibility study analysis would be very easily determined and possibly solved with the conventional equipment which is readily available in the existing bagasse pulp mills of latest modern design.

The other major problem to be solved is that of the marketability of both types of kenaf paper pulps to the non-integrated paper mills in Thailand and the other Mekong Basin countries and the determination of the tests and qualities that could be achieved on all major grades of paper if made from 100 percent kenaf pulp fibrous furnishes. The complete commercial study on these two items could easily be carried out where the bagasse pulp mill has a bleach plant and is integrated with a paper mill that could run pulp over the paper machine and could make some of the desired grades of paper.

It is the conclusion of the Consultants that, from the standpoint of the pulp mill, kenaf paper pulp can be made and evaluated as a commercial reality in a very short time by this direct move to apply the knowledge already developed in the laboratories to full scale mill tests as outlined. This will have to be done eventually anyway before a kenaf pulp mill is built. It will also save the time and money that may be spent under the present state of affairs in further laboratory investigations on kenaf pulping over another 25 years developing information on which a kenaf pulp mill might be built.

Other possible avenues of research and development on making kenaf into pulp could also be explored at the same time, although they are not required for the project outlined in this Study. These investigations would cover the development of equipment for separating the bast ribbon from the woody core material by either wet or dry processes at the mill to determine the possibilities for improving pulp properties by separate pulping of the two components and/or lowering the cost of the bast ribbon pulp by using the mechanically separated core material for fuel or mechanical pulp for newsprint, particleboard, or chemical by-products. However, these additional developments are not necessary before a kenaf pulp mill can be built with a chance for viability as is the case requiring the direct approach to mill trials that has been recommended in this Study.

3.4. Draft Terms of Reference, Additional Development Program for Pulp and Paper from Kenaf

The foregoing discussion in Section 3.3 of this Chapter X has been based on the judgement that both species of kenaf will yield suitable whole stalk or bast ribbon pulps of equivalent physical properties and papermaking characteristics. Therefore, as soon as a satisfactory kenaf fiberizing system could be installed at an existing mill, commercial pulping runs to produce pulp and paper for market trials could begin. This would require that the proper equipment for raw fiber cleaning and pulping and bleaching and papermaking facilities be available in the existing mill and that an adequate supply of one of both species and types of kenaf fibrous raw materials, preferably in baled, field dried form, would be available for the tests at the required time.

These are the basic requirements for the development and research work that need to be done, from the pulping standpoint, before a full feasibility study should be made for a kenaf paper pulp mill. The timing of the final feasibility study would have to be based on the success of the proposed agro-economic studies to assure an adequate supply of baled field dried kenaf to the proposed mill. The Consultants believe that the technical and financial analyses in the present pre-feasibility Study have sufficient accuracy and validity with regard to the pulp mill part of the project to suffice through the period of pulp marketing trials which are estimated to take about two to three years from the start of any new program following the present Study.

There are, of course, a number of other technical investigations that could be carried on in parallel with those recommended for primary action, based upon the availability of funds and research facilities. However, as stated earlier in this section, these laboratory studies would not be required for the establishment of a kenaf whole stalk paper pulp mill indicated as being financially viable in Chapter IX of this Study.

Suggestions for additional laboratory and pilot plant studies on kenaf are:

Comparative Pulping Evaluations

There could be carried on a continuing and standard comparative evaluation laboratory pulping program for the varieties of kenaf grown and harvested under significantly different conditions in the agro-economic research program that has been recommended for further study.

Development of Equipment and Processes for Separating Kenaf Stalk Fiber Components Before Pulping

Developmental work on systems for wet or dry mechanical separation of the kenaf woody core material and bast ribbon from whole stalk at the mill would be worthwhile and would cover an area of investigation not thoroughly studied so far.

Study of Equipment and Processes for Fractionating Kenaf Stalk Components after Pulping

Another avenue of investigation would be to develop a process for separating the fiber fractions of the kenaf whole stalk after pulping and preferably before bleaching. If successful, this would make available three or four types of pulp with properties ranging from those of woody core material pulp to the other extreme of bast ribbon pulp. If a sufficient market could be found for the woody core material type of pulp, the economics for production of the bast ribbon type of pulp from the whole stalk would be improved measurably.

Development of Newsprint from Kenaf

The development of mechanical, thermomechanical, or chemimechanical pulps for newsprint from whole stalk kenaf would be a great step forward in the utilization of this fibrous raw material and it might serve as 100 percent of the fibrous furnish. The higher pulp strength properties that would possibly be obtained from kenaf whole stalk mechanical pulp because of its bast fiber content, as compared to mechanical pulp from wood or bagasse or the woody core fraction of kenaf, might eliminate the need for the chemical pulp fraction in the furnish usually required for maintaining the physical strength of newsprint so that it will run at high speeds through the printing presses.

Further investigations should also be made to determine the qualities of the mechanical type pulps from the woody core material that would be useful for newsprint and in the low cost printing and writing grades of paper as well as tissue and towel-making products.

These tests should be carried out in existing mills or pilot plants of large scale where comparable pulps are being made on at least a semi-commercial basis from wood so that paper can be made with these pulps. If the pulps produced meet the quality

requirements for newsprint, a pre-feasibility study for productive facilities for a newsprint mill in conjunction with the kenaf paper pulp mill covered by this report should be carried out.

Investigation of Kenaf for Particleboard

As an alternative use for the woody core material that could be made available to the Mekong Basin paper pulp mill from the production of kenaf bast ribbon for pulping or textile fibers, its possibilities for the manufacture of particleboard appear to be the most promising. Therefore, the technical development work should be carried out in conjunction with several of the large research laboratories of international firms which supply the machinery for such plants. A market and pre-feasibility study should be made based on the data gathered in these tests.

Conclusion

It is obvious from the preceding discussion of the research possibilities on kenaf in the fiber preparation, pulping, and papermaking areas that a practical approach to commercial production as soon as possible will be the most beneficial. Careful planning, direction, and supervision of all or any part of this work will be required to achieve the optimum results at a reasonable expenditure in a minimum time span so that the information obtained would be applicable for the kenaf paper pulp mill that the Consultants have planned in this Study.

CHAPTER XI - PROJECT ORGANIZATION AND MANAGEMENT

1. Introduction

Within the terms of reference of the usual pre-feasibility or feasibility studies prepared for projects to be subsequently submitted for financing consideration by such institutions as the World Bank, the Inter-American, African and Asian Development Banks, or to semi-Governmental or private lending agencies, the above chapter heading refers to the description of the project Executing Agency or Agencies, be they Governmental or private, their organizational structure and the proposed project management procedures, as well as to machinery, equipment, installation and services procurement, so as to enable the promotional and/or financing agency to convince itself of the suitability and efficacy of the envisaged project organization and management.

Such Executing Agency evaluation is possible and, in fact, an essential component of any pre-feasibility or feasibility study where that agency is known. This, however, is not the case in the present Study which covers the establishment "in principle" of a kenaf pulp and paper industry in the Lower Mekong Basin but in which, at this time, neither its definite location can be established nor can its future Executing Agency be identified.

In view of the foregoing, this present Chapter XI will be limited to a discussion of suggested organizational and management procedures only of the kenaf pulp and paper project.

2. The Kenaf Raw Material Supply

In the preceding chapters of this Study, the conclusion has been reached that, under Lower Mekong Basin conditions:

- (i) The most suitable raw material is kenaf whole stalks, unchopped, either as such or with the bast stripped from the central core and the two stalk components being baled and delivered separately to the mill yard gate;
- (ii) The kenaf will continue to be produced by small holders rather than on a commercial plantation scale;
- (iii) The kenaf raw material will be procured through the established balers and traders and through farmers organizations, rather than through a pulp mill operated purchasing organization.

The above production and procurement system requires only a minimum of intervention on the part of the mill which would, in fact, be limited to the establishment of a Procurement Office staffed by a manager, one or two deputies, and some clerical assistants.

The small holder production of whole stalks, unchopped and with the bast ribbon stripped off or not, does not require any sophisticated mechanical equipment which the mill might be expected to supply or operate. Kenaf procurement through the established balers and traders eliminates the necessity for the mill to establish its own collection, satellite storage, baling and transport organization; the highly desirable and, hopefully, rapidly expanding inclusion of farmers organizations into the kenaf raw material supply system would not change the situation, as far as the mill is concerned, since these organizations would do their own kenaf collecting from their members, operate their own storage facilities and baling plants or sub-contract for these services with existing baling plants, and deliver the raw material to the mill gate with their own or leased trucks.

However, this Study also envisages the establishment of a mill operated Demonstration Farm (Chapter V, Section 7.) and discusses the organization of such a farm in terms of 240 ha. units. As shown in Table VIII.8., each such unit would be staffed by one Farm Manager assisted by two Field Managers and a varying crew of tractor and equipment operators and attendants, depending upon the type of kenaf raw material being produced, i.e. whole stalks, chopped stalks or bast ribbon, from a minimum of 4 tractor operators and their helpers plus 5 unskilled workers for whole and chopped stalk production to a

maximum of an additional 3 ribboner operators and 78 attendants for bast ribbon production, with all unskilled labor being required for only 4 months each year. The above staffing pattern was established on the assumption that the Demonstration Farm Unit or Units would be directly under the overall management of the mill and would, therefore, not require such administrative staff as accountants, storekeepers, clerks, etc.

On the other hand, it would be highly desirable for the kenaf for paper pulp project to operate its own limited extension and demonstration service to its small holder kenaf suppliers, if only to supplement any existing Government services. It is pointed out that, on the assumption of a ₦600/rai (\$187.50/ha.) gross revenue to the small holders from the sale of 1.2 FDMT of whole stalks to the mill, as used in this Study, an increase in yield of only 20 percent to 1.44 FDMT/rai would raise that revenue by ₦120 (\$6.00). Further assuming that this increase in revenue is evenly divided between the small holders and the mill, the latter would reduce its raw material costs by ₦42 (\$2.10) per FDMT or by some ₦8.65 million (\$432,500) per year for its approximately 206,000 FDMT annual raw material requirements, thus covering the costs of any kenaf for paper pulp project operated Demonstration Farms and extension services many times over.

3. Paper Pulp Production

3.1. Introduction

In Section 3 of Chapter X it has been pointed out by the Consultants that the knowledge on the pulping of kenaf whole stalk and bast ribbon, as derived from extensive laboratory and pilot plant investigations in many places in the world, is sufficient for the next major step to semi-commercial and full scale runs of kenaf pulps for market trials. It is considered that, if this is not done soon and as a matter of primary importance, it will be a long time before it can be predicted with a guaranteed degree of certainty that kenaf whole stalk pulp would be as acceptable to the paper mills in Thailand and the other Mekong Basin countries as the hardwood and softwood sulfate chemical pulps that have been imported. The bamboo and bagasse pulps that could be produced in Thailand and which have adequate and well known papermaking properties for most grades of paper would also enter into this consideration.

In both the agro-economic and pulp/paper sections of this Study it has been recognized that there should be a worldwide coordination of the work that is being done on all aspects of kenaf for pulp and paper. In the case of the Mekong Project mill, it should be planned that the specific area be chosen for the proposed agro-economic studies with respect to the optimum primary pulp mill sites which have been located in this present investigation. It is absolutely necessary that the fibrous raw material supply be assured in sufficient quantity for the long term operation of the mill and it appears that the area in Northeast Thailand in the Mekong Basin would be the best location for the necessary future agro-economic studies on kenaf, preparatory to more serious consideration for building the pulp mill. By choosing a pinpointed location for the kenaf project, it becomes possible to recommend the executing agency and consulting services to carry out the next stages of study.

3.2. The Executing Agency

The arrangement for the present Study and the handling of the contract and project by the Executive Agent of The Committee for Coordination of Investigations of the Lower Mekong Basin have been very satisfactory. The development of further investigations of kenaf for paper pulp in the Mekong Basin could best be carried out under this international agency in conjunction with other international and national agencies and foreign governments that would provide the necessary supporting grants. The studies on kenaf are believed to be of such immediate worldwide significance for the building of pulp and paper industries in both developed and developing countries that support might well be obtained from the United Nations Development Programme, the World Bank and the Asian Development Bank, as well as from the Governments of Thailand and the other Mekong riparian countries.

It is believed that the U.S. Government would look very favorably upon this type of project for its support because it would be an excellent opportunity to bring to commercial application the great amount of research work that has been carried out on kenaf by the U.S. Department of Agriculture at its pulping laboratories and through the agronomic investigations supported by its grants at the various USDA and state agricultural experiment stations where kenaf has been grown for tests. It is also believed that the Governments of some of the other countries where kenaf is being grown or considered as a source of fiber for papermaking would make grants supporting these semi-commercial studies in lieu of carrying on some of the investigations that are going on at their own experiment stations and pulping laboratories.

There would be additional benefits from coordinating further research efforts on growing and pulping kenaf in Asia under the Mekong Committee. It would make it possible to centralize the agricultural development effort exactly in the place where it would have probably the greatest impact for not only pulp and paper but for the existing textile fiber production as well. Because of the major productive capacity for kenaf textile fiber which already exists in the Mekong Basin area in Thailand, it is only logical that this area with its existing infrastructure be chosen as the agricultural base for further research relative to pulp and paper production where the mill would be established.

3.3. Consulting Services for the Pulp and Paper Studies

There is no question but that the agricultural development studies recommended would best be carried out near the primary pulp mill sites already located in this Study. However, the pulp and paper investigations would have to be carried out elsewhere in an existing mill because there are no such installations in the Mekong Basin area.

Based upon the expectation that kenaf grown in the tropics outside the Mekong Basin area will yield pulps with quality and characteristics equivalent to pulps that could be produced from the varieties of kenaf presently available or that would be grown in that area, the pulp mill tests are not limited to this particular area for fibrous raw material supply. It is more important that the existing mills chosen for the tests have the most advantageous productive facilities for nonwood plant fiber pulps. Then the kenaf for tests can be shipped from the Mekong Basin area, if the trials are to be made in Thailand, or it could be grown in some of the other countries which are experimenting with it and where the required processing facilities to make pulp exist.

The consulting and management services for the kenaf pulp mill trials and marketing tests could best be furnished by an independent consulting firm that would not be directly involved later on in partially owning or promoting the mill, as a contractor to build it, or furnishing equipment or detailed engineering services for it. The same firm would then logically be in a position to work out objectively the best combination of processes and equipment to be considered in the final feasibility study they would make for the mill. It is believed that for laying the final groundwork for this kenaf pulp project in the shortest possible time, a consulting firm that is experienced and specializing in the pulping of nonwood plant fibers should be chosen to manage the project for the Mekong Committee, where innovative and practical development are required to reach the final stage of commercial implementation.

3.4. Pulp and Paper Mills for Commercial Trials with Kenaf

It appears that there are at least two nonwood plant fiber pulp mills that should be considered for making kenaf pulp, assuming that both could have an equal supply of field dried whole stalk or bast ribbon kenaf. These would be the Siam Kraft Paper Co., Ltd., in Thailand or the United Pulp and Paper Co. (UPPC) in the Philippines. With the installation of proper chopping and fiberizing equipment at either of these two plants, they would be able to process both types of unbleached pulp. The paper mill at Siam Kraft could manufacture linerboard and bag papers with kenaf while the UPPC mill could produce extensible multiwall bag papers using the Clupak unit. Both mills could also produce wet lap or wet pressed pulps which could be transported to existing bleach plants in the respective countries for further processing.

Both of these mills have well equipped technical control laboratories where required tests could be carried out for the production runs. In addition to these facilities, consideration should also be given to the use of the pulp and paper laboratory and staff at the Research Division of the Department of Science of the Ministry of Industry of Thailand in Bangkok. This technical organization could be used very advantageously for making the necessary chemical and physical analyses and the pulping trials for comparing and screening the varieties of kenaf produced in the agro-economic development trials in the Mekong Basin area.

The Consultants recognize that these suggestions are quite general and leave considerable latitude for change in the possible future developmental program. A detailed investigation and discussion of the possibilities with these two companies, and others around the world that might be able to pulp kenaf, should be carried out immediately as the next step in an ongoing program to develop paper pulp from kenaf.

ANNEX I

DESCRIPTIVE LEGEND FOR THE GENERAL
SOIL MAP OF THE LOWER MEKONG BASIN

by W. van der Kevie

Introduction

The General Soil Map of the Lower Mekong Basin is based chiefly on the General Soil Map of Thailand by F.R. Moormann and S. Rojanasoonthon, (Scale 1:1,250,000) (8), the General Soil Map of Cambodia by C.D. Crocker (Scale 1:1,000,000) (1), and the General Soil Map of Viet-Nam by F.R. Moormann (Scale 1:1,000,000) (7), while for the Laos part the soils map in the Mekong atlas (13) prepared by the U.S. Agency for International Development was used. The soil boundaries in the Delta were derived from the soil map of the Mekong Delta in Viet-Nam (1:500,000), prepared by Dr. Truong Dinh Phu and included in the report on Mekong Development by the Development and Resources Corporation (2). Large areas in Thailand have soil boundaries based on recent soil and land capability maps of provincial soil surveys (Scale 1:100,000 and 1:250,000) (5 and 10).

Numerous meetings were held with soil scientists and specialists in agriculture in all four countries. These discussions showed the necessity to change some soil boundaries of the original documents and they were particularly informative for the classification of the soils and the interpretation of their capability for agriculture.

Numerous soil descriptions and laboratory analysis data were available in Thailand and Cambodia which were also very useful for a proper classification of the soils.

Map Reliability

The reliability of the soil map varies a great deal with the detail and quality of the original documents on which the map is based, and only those parts of the map, mainly located in Thailand, that are based on soil surveys, have good reliability. Many soil studies were carried out in Cambodia and Viet-Nam and reliability of the map for those countries may be considered fair. Very little information was available for Laos and this part of the map has only a poor reliability though the boundaries delineating the mountainous soils (Orthic Acrisols, stony phase) are rather accurate.

The Legend

For the legend of the General Soil Map the names and definitions of the soil units on the FAO/UNESCO Soil Map of the World were used. These units have been established on the basis of present knowledge of genesis, characteristics and distribution of the major soils of the earth's surface. The soil names that were adopted for the World Soil Map have partly been taken from existing soils literature (f.i. Rendzinas, Vertisols, Solonchaks, Planosols and others), but also many new names had to be given in order to avoid the confusion that was caused by several traditional names having different meanings in different countries (f.i. Lateritic Soils, Alluvial Soils or Brown Soils). The new names are chiefly formed from Greek and Latin roots and are easy to pronounce in most languages.

It should be emphasized that the collection of soil units of the World Soil Map legend is not intended to form a new soil classification system, and the various subdivisions do not strictly adhere to taxonomic rules and may belong to different levels of generalization. In principle however, the soil units used here correspond to the "great group" level as distinguished in various soil classification systems. In establishing these soil units their significance as resources for agricultural production, and the feasibility of representing them on small scale maps have been taken into account. Yet, the separate units are defined in such way that soil units in existing soil classification systems or shown on existing maps or to be mapped in the future, can be compared and correlated.

In the descriptions of the map units given below and the soils included in them, no definitions of the soil units are given - therefore reference is given to the "Definitions of Soil Units for the Soil Map of the World" - but for each map general soil descriptions with indications to their use and suitability for agricultural production are given. Yet, it should be emphasized that the soil names used here are in strict accordance with the definitions which have been agreed upon for the World Soil Map.

Each map unit consists of a soil group or an association of soil groups. The associations are composed of a dominant soil group covering more than 50 percent of the map unit,* and one or two subdominant soil groups covering at least 20 percent. Soil groups which cover less than 20 percent of the area are mentioned as inclusions.

For the dominant soil groups within the map units the textural class of the upper 30 cm. of the soil profile (weighted average) and the slope class reflecting the topography of the soil association is indicated in the legend. Soil phases are distinguished to indicate the presence of indurated laterite layers (petric phase) or hard rock and stoniness (stony phase) at shallow depths, or salinity (saline phase) at least in a large part of the soils of the association. These phases are shown on the map by an overprint.

* This is not necessarily so for the map units on the World Soil Map which is presented at a much smaller scale (1:5,000,000).

Description of the Map Units

1. Eutric Fluvisols

The Eutric Fluvisols are the soils designated by Crocker (1) on the soil map of Cambodia and by Moormann (7) on the soil map of Viet-Nam as Brown Alluvial Soils of the river levees.

They are recent alluvial soils occurring on both sides of the Mekong River and on sandy islands in the river. These soils generally have a loamy to clay loam texture and are well to moderately well drained. They have no diagnostic horizons, except possibly an ochric (light coloured) A horizon. Organic matter content is low but varies within the profile. The soils have a high fertility and are very productive. They may be flooded for short periods at the peak of the rainy season. .

Vegetation on these soils may be dense tropical forest on the higher areas, but the sandy islands that are only exposed in the dry season have only a sparse growth of bushes. Most of the soils are used for a wide variety of upland crops, vegetables and fruit trees. They are well suited for field crops (suitability class U-II) and are particularly suited for tree crops.

Inclusions of various other soils are Eutric and Mollic Gleysols on more poorly drained alluvium which occurs often in narrow elongated depressions alongside the levee soils. Parts of the map unit are alluvial complexes with slightly undulating relief and variable texture and drainage. The Eutric Fluvisols occur also on narrow levees along the Mekong River in Thailand and Laos and along most other rivers, but their extension is too small to be indicated on the map.

2. Eutric Fluvisols, Saline Phase, Associated with Eutric Gleysols

The majority of this unit is Eutric Fluvisols occurring close to the coast in the Mekong Delta. They are quite different from the Eutric Fluvisols of map unit No. 1, as they generally have a clayey texture and are poorly drained. Part of these soils are flooded with brackish water at very high tides and they are often somewhat saline at least during part of the year. These soils are included in the Undifferentiated Alluvial Soils on the soil map of Viet-Nam.

They have a weakly developed profile with mottles in the upper part but with soft, reduced clay at shallow depth. The A horizon has a dark grey colour while the subsoil is grey. Soil reaction is moderately acid to neutral and soil fertility is quite high.

The soils are associated with Eutric Gleysols which have a somewhat better developed profile where the soft reduced clay occurs at larger depth and structure is fine blocky. Inclusions are Gleyic Cambisols of former coastal ridges and Thionic Fluvisols.

The soils are mainly used for transplanted rice for which they are well suited (suitability class P-II). Coconuts are grown on ridges.

3. Thionic Fluvisols

The Thionic Fluvisols of this map unit are the Very Acid Alluvial Soils of the soil map of Viet-Nam. They are very poorly drained, clayey soils on brackish water alluvium and have a thick, very dark grey to black horizon overlying a grey to greyish brown clay with strong brownish yellow and pale yellow (jarosite) mottles (cat clay horizon). This horizon has a weak to moderate blocky structure, but overlies a reduced, dark grey, massive mud clay at shallow depth. The soils are characterized by a very acid soil reaction with pH generally below 4.0, even in the surface horizon. Dried soil of the subsoil may have pH values of 2.5 to 3.5.

The Thionic Fluvisols are poorly suited for any type of agriculture due to their severe acidity (suitability classes U-IV/P-IV). They are mainly covered with reeds and other swamp vegetation. In the rainy season they are deeply flooded but they dry out for a short period in the dry season.

Inclusions are small areas of Humic Gleysols, which are somewhat less acid.

4. Thionic Fluvisols Associated with Humic Gleysols

The soils of this map unit cover most of the Acid Alluvial Soils of the soil map of Viet-Nam and the Alumisols of the soil map of Cambodia. They are very poorly to poorly drained clayey soils on brackish water alluvium and have a thick, very dark grey to black A horizon overlying a deep, grey to greyish brown clay B horizon with strong yellowish brown or yellow (jarosite) mottles.

Most soils have a very low pH with values below pH 3.5 within 100 cm. of the surface but a considerable area has somewhat less acid soils that should be grouped with the Humic Gleysols, but are here included in this map unit.

Vegetation on these soils is mainly reeds, rushes and other swamp vegetation, though also paddy and some sugar cane or pineapple on ridges are grown on these soils. Some improvement is possible by irrigation and drainage, liming and application of fertilizers (particularly phosphates), and the rice area has considerably extended in the last decade. On the General Land Capability map the soils are included in suitability class P-III (moderately suited for paddy).

5. Eutric Gleysols

The Eutric Gleysols are the soils of the river backswamps that are deeply flooded for a prolonged period during the rainy season. They are included in the Alluvials and Lacustrine Alluvials on the soil map of Cambodia, the Undifferentiated Alluvial soils on the soil map of Viet-Nam and the Alluvial Soils on recent fresh water alluvium on the soil map of Thailand.

These soils are clayey, somewhat poorly to poorly drained, with grey to greyish brown colours and strong brown or yellowish brown mottles. They have a dark grey or dark greyish brown A horizon and a well structured deep B horizon. The soils dry out deeply in the dry season and vertic characteristics such as deep cracks and slickensides are normal in many of them.

The soils have an acid to neutral soil reaction but a base saturation of more than 50 percent. They have a rather high fertility and are well suited for paddy. They should be very well suited under conditions of water control and irrigation. Most soils are used for broadcast rice only, but some upland crops such as mung beans or jute are grown locally. Swamp forest occurs in some areas such as near the Tonle Sap Lake in Cambodia.

Inclusions are Mollic Gleysols having a very dark coloured A horizon and higher organic matter content, Humic Gleysols combining a very dark horizon with a low pH and base saturation, and Eutric Fluvisols which may be either well drained levee soils or very poorly drained marshy soils of the deepest parts of the backswamps.

6. Eutric Gleysols Associated with Mollic Gleysols

The majority of this map unit consists of Eutric Gleysols which are similar to those of map unit No. 5, but they are associated with Mollic Gleysols which may cover close to 40 percent of the association. They are also included in the Alluvial Soils of the soil maps of Cambodia, Viet-Nam and Thailand. They occur in the upper part of the Mekong Delta. They are deeply flooded for a prolonged period and are dry for a shorter period than the Eutric Gleysols of the river valleys.

The soils are clayey and have mainly grey colours with strong yellowish brown and brown mottles. The soil reaction of these soils is strongly acid to slightly acid but the base saturation is more than 50 percent. The Mollic Gleysols occur normally somewhat farther away from the main rivers than the Eutric Gleysols and are flooded for a longer period. They are distinguished because of their very dark surface horizon.

The soils are used mainly for broadcast deep water rice, but some upland crops such as various kinds of beans are grown in the early rainy season. They are well suited for rice (suitability class P-II) and would be even very well suited under conditions of water control and irrigation. Inclusions are Humic Gleysols having a dark surface and a lower pH and base saturation, and Thionic Fluvisols with a very acid catclay horizon.

7. Mollic Gleysols

Most of the Mollic Gleysols occur in the lower part of the Mekong Delta in Viet-Nam. They are included in the Undifferentiated Alluvial Soils of the Viet-Nam soil map.

The soils of this map unit are generally not flooded by river water, though they are submerged with rain water during the rainy season when transplanted rice is grown.

They are somewhat poorly to poorly drained soils with greyish brown to reddish grey colours and a very dark grey to dark reddish brown surface horizon. The subsurface horizons are strongly mottled with reddish yellow and strong brown mottles. The soils have a well developed B horizon with moderate fine blocky structure. Soft, reduced subsoil occurs below 150 cm. depth.

These soils have a slightly acid to mildly alkaline soil reaction and may be somewhat saline in the subsoil. They are fertile and very well suited for paddy and moderately suited for upland crops. (suitability classes P-I/U-III)

Most of the land is in use for transplanted rice but large areas are also used for fruit trees, vegetables and some upland crops, which are mainly grown on ridges.

Inclusions are Eutric Gleysols, Eutric Fluvisols and some Gleyic Cambisols on loamy textured ridges.

8. Humic Gleysols Associated with Dystric Gleysols, Petric Phases

These soils are the Plinthitic Hydromorphics of the soil map of Cambodia. They occur in a flat plain, which is very wet in the rainy season.

The soils consist of dark, clayey soils, underlain at shallow depth by a thick, very hard layer of consolidated laterite. The surface soil contains many laterite concretions. The soils have a low pH and base saturation and have a low fertility. They are somewhat poorly to poorly drained.

Most of the soils are covered with dense forest and they are poorly suited for both rice and upland crops (suitability classes P-IV/U-IV).

9. Lithosols Associated with Haplic Phaeozems

This map unit includes very shallow soils on basalt plateaux or limestone hills. The limestone hills are normally very steep but the basaltic areas have an undulating to rolling relief. The map unit coincides with the Basic Lithosols of the soil map of Cambodia, the Shallow Regurs of the soil map of Viet-Nam and the limestone crags and lava plateaux of the soil map of Thailand.

Most areas of this map unit have less than 10 cm. soil overlying bedrock, but somewhat deeper, stony soils with a dark, friable surface occur also quite extensively, particularly on basalt. The soils have a neutral to mildly alkaline soil reaction and a high base saturation. Texture is mostly clay or clay loam.

The soils are poorly suited for cultivation (suitability class U-IV) due to their shallowness. They are covered with forest or shrubs though some crops are grown where slightly deeper soils occur.

Inclusions are Pellic Vertisols, Calcaric Cambisols and Rendzinas.

10. Luvic Arenosols

The Luvic Arenosols occur quite extensively in South Viet-Nam. They are the Sandy Podzolic Soils on the Viet-Nam soil map.

The soils occur on old sandstone surfaces in slightly undulating to rolling areas. They are very sandy soils with yellowish to brownish colours. They have certain characteristics of the Acrisols but are too sandy to be included in this group. The organic matter content and cation exchange complex are very low and these soils are very infertile. They are excessively drained and have a very low water holding capacity. Some of the soils are stony.

The soils are covered with poor, open dipterocarp forest and are poorly suited for cultivation (suitability class U-IV)

11. Rendzinas Associated with Pellic Vertisols and
Calcaric Cambisols

This map unit coincides with the Regurs of West Cambodia. The map unit includes mainly Rendzinas, which are shallow, black soils on limestone colluvium and marls. They are associated with Pellic Vertisols which are deeper soils having a heavy clay texture.

The Rendzinas have a 20 to 50 cm. thick, granular, black clay horizon overlying gravelly marl. They have a neutral to alkaline soil reaction. Soil fertility is high but shallowness and drought are limiting factors for agriculture.

The Pellic Vertisols are deeper and much less friable though structure in the surface may be granular. These soils are very sticky when wet and very hard when dry. They develop deep cracks in the dry season. They generally occur in the somewhat lower areas. They have a thick, black to very dark grey A horizon over soft marl or calcareous clay. They have a slightly acid to alkaline soil reaction and very high cation exchange capacity and base saturation.

Vegetation on these soils is secondary forest with much bamboo. Many crops such as cotton, maize, jute and rice are grown on them. The deeper Rendzinas and the better drained Vertisols are well suited for upland crops, while the lower Vertisols are used for rice (suitability classes U-II/P-III).

Inclusions are shallow to moderately deep, reddish brown, Chromic Cambisols and Lithosols on limestone, and deep, friable Dystric Nitosols.

12. Pellic Vertisols Associated with Chromic Vertisols

This map unit includes the Regurs of Thailand, Laos and East Cambodia mainly developed on basaltic parent rock. The majority of these soils is dark coloured Pellic Vertisols, which are associated with brownish Chromic Vertisols.

Most of the Pellic Vertisols are somewhat poorly drained clay soils, having a thick, black A horizon with mottles or hard laterite concretions. They have a strongly acid to neutral soil reaction and high cation exchange capacity and base saturation. They consist of montmorillonitic clays that swell strongly when wet and shrink when dry. They have deep cracks when dry and slickensides throughout. When wet the soils are very sticky and difficult to work. Structure in the surface may be blocky but is often strongly granular.

The Chromic Vertisols are somewhat better drained soils having dark brown to brown colours. They occupy the higher areas of a nearly flat to gently undulating landscape.

The soils are covered with dense tropical forest in some areas of East Cambodia or more open forest with bamboo in other areas. Large areas, however, are used for paddy and upland crops such as maize, banana and pineapples. The soils are well suited for paddy and moderately suited for upland crops (suitability classes P-II/U-III).

Inclusions are Rhodic Ferralsols and Gleyic Acrisols.

13. Gleyic Solonchaks Associated with Thionic and Eutric Fluvisols

This map unit occurs along the coast and includes a narrow strip of tidal swamp soils. It includes the Saline Alluvial Soils of the soil map of Viet-Nam and the coastal complex of the Cambodia soil map.

The majority of soils is nearly completely reduced, very poorly drained mud clays with a high salinity. They are associated with Thionic Fluvisols, in this case potentially acid mud clays with a high sulphur content that will become extremely acid if drained. Other associated soils are Eutric Fluvisols, poorly drained soils having a salinity that is too low for Gleyic Solonchaks (electrical conductivity of saturation extract of less than 15 ohms).

Vegetation is mainly mangrove forest. Large areas are used for salt making in the dry season and also some shrimp farms exist. On some of the less saline soils coconuts are grown on ridged soils. Under present conditions the soils are poorly suited for upland crops and paddy (suitability classes U-IV/P-IV), but if protected against flooding with salt water they could be good paddy soils. However, with much less costs the land could be developed for shrimp production.

Eutric Regosols occurring on sand ridges occur as inclusions, particularly in Cambodia.

14. Gleyic Cambisols, Associated with Gleyic Luvisols

This map unit covers only very small areas in the Mekong Delta, which are indicated on the soil map of Viet-Nam as Regosols on white and yellow dune sands. However, in the Delta these soils have a loamy texture and a weakly developed profile.

The Gleyic Cambisols of this map unit occur on very low ridges surrounded by clayey Gleysols or Fluvisols on marine deposits. They have normally a greyish brown to brown surface horizon over yellowish brown to brown or strong brown B horizon with distinct mottles. The C horizon is light grey to light greyish brown. The soils have a very low organic matter content and an acid to neutral soil reaction. Some of the soils are slightly saline. They are usually moderately well drained.

The Gleyic Luvisols are similar soils on somewhat older ridges with a distinct textural B horizon having clay coatings and a higher clay content than the surface horizon.

The soils are mainly in use for settlement areas with fruit trees and some field crops such as maize and vegetables.

Inclusions in this map unit are poorly drained Mollic Gleysols and Eutric Fluvisols and some Eutric Regosols that are very sandy and well drained.

15. Ferralic Cambisols associated with Ferric Acrisols

The Ferralic Cambisols are the Grey Podzolic Soils of the soil map of Thailand and the Red Yellow Podzols of Cambodia, occurring on gently undulating old alluvial terraces.

These soils are very deep and characterized by a greyish brown, sandy loam A horizon overlying a brown or light yellowish brown sandy loam or sandy clay loam B horizon. Clay content increases very gradually with depth and horizon transitions are gradual or diffuse. Faint mottles occur sometimes in the lower part of the soil profile. No indications of illuviated clay such as clay coatings can be distinguished and it seems that these very strongly weathered soils are grading to the Ferralsols. Structure is very weak or massive. The content of weatherable minerals and cation exchange capacity are very low. The soil reaction is normally very acid. Organic matter content is low, though may be higher depending on vegetation cover.

Associated soils are the Ferric Acrisols. These soils are somewhat similar to the Ferralic Cambisols. They also have a sandy loam surface overlying a sandy clay loam subsoil but the generally pinkish grey to light brown B horizon has strong reddish mottles and many hard iron concretions. Clay coatings in the B horizon can be observed occasionally.

Vegetation is mostly open dipterocarp forest. The soils are used for shifting cultivation with the main crops grown being kenaf in the driest areas, and cassava. Fruit trees are often grown near villages. Due to their low fertility and drought hazards these soils are only moderately suited for upland crops (suitability class U-III). The choice of crops is very limited and only with careful soil management could these soils be used for permanent agriculture.

Inclusions are Gleyic and Orthic Acrisols and Luvic Arenosols.

16. Gleyic Luvisols Associated with Orthic Luvisols and
Eutric Gleysols

The soils of this map unit coincide with the Brown Hydromorphic Soils of the soil map of Cambodia and certain parts of the Low Humic Gley Soils in North Thailand.

The Gleyic Luvisols are the dominant soils on sub-recent (called semi-recent in Thailand) alluvium. They are greyish brown soils with a loam to clay loam surface soil overlying a well developed textural B horizon characterized by a finer texture and the occurrence of clay coatings. These soils have a low to moderate organic matter content, a moderate to high cation exchange capacity, high base saturation and acid to neutral soil reaction. The soils are strongly mottled and somewhat poorly to poorly drained. They occur in former backswamp areas of a fluviatile landscape and are associated with better drained Orthic Luvisols on old river levees and Eutric Gleysols in the lowest parts of the backswamps.

The soils have moderate fertility and are very well suited for paddy. They are seldom flooded with river water and most are used for transplanted, rainfed or irrigated paddy. Certain upland crops such as beans, jute, tobacco and sugar cane can be grown on these soils, while the Orthic Luvisols are even more suited for these crops due to better drainage. The soils of this map unit are very well suited for gravity irrigation and implementation of irrigation projects would be most beneficial, particularly for increased paddy production (suitability classes P-I/U-III).

Inclusions are Gleyic Acrisols and Eutric Fluvisols.

17. Orthic Acrisols, Stony Phase, Associated with Lithosols

This map unit includes the Acid Lithosols of the soil map of Cambodia, the Mountain Soils of the soil map of Viet-Nam and the Red Yellow Podzolic and Reddish Brown Lateritic Soils on steep land of the soil map of Thailand.

The soils of this map unit are mainly shallow and stony Orthic Acrisols occurring on all sorts of acid and intermediate rocks in mountainous areas or on strongly dissected plateaux. Relief is generally rolling to very steep.

The Orthic Acrisols of this map unit have a loamy or clayey texture in the surface horizon overlying a textural B horizon with a higher clay content. The appearance of the soils is extremely variable. Colours vary from red to yellowish brown. Organic matter content ranges from low to very high, depending on vegetation cover, slope, elevation and drainage. Though most soils are shallow and stony, deep soils occur in many places. The soil reaction is generally strongly acid and their fertility is low and depends mainly on the organic matter content. Also physical characteristics are unfavourable and most soils are very susceptible to erosion.

The majority of the soils is under forest, both dense tropical forest (evergreen or dry deciduous) and open secondary forest. Other parts are covered by savannah. Many of the soils are used for shifting cultivation and all kinds of subsistence crops are grown on them. In some small areas rubber or tea are grown. Due to their shallowness and erosion susceptibility these soils are poorly suited for upland crops (suitability class U-IV) and should remain under forest, though locally plantation crops may be grown.

The Orthic Acrisols are associated with very shallow Lithosols having less than 10 cm. soil overlying bedrock. Inclusions are Chromic Cambisols, which are relatively young soils that have no textural B horizon and Humic Acrisols having a high humus content, occurring in the higher mountain areas where rainfall is high.

18. Orthic Acrisols Associated with Dystric Nitosols and Ferralic Cambisols

The Orthic Acrisols are the deeper Red Yellow Podzolic Soils of the soil maps of Viet-Nam and Thailand occurring on undulating to rolling land. In Cambodia these soils are quite rare and occur only as inclusions of the Ferralic Cambisols*.

The Orthic Acrisols are very well developed soils on old alluvial terraces, slope colluvium or residuum of acid to intermediate rocks.

* The map unit of Red Yellow Podzols on the soil map of Cambodia includes only small areas of Orthic Acrisols (Red Yellow Podzolic Soils) and was therefore grouped on the soil map of the Lower Mekong Basin with the Ferralic Cambisols.

They have a sandy loam A horizon overlying a clay loam or clay textural B horizon, normally characterized by the presence of clay coatings and having a blocky structure. Some of the soils may be rather shallow and stony, or gravelly. The soils have a rather low water holding capacity and become very dry in the dry season.

The A horizon under natural forest is very dark and has a high organic matter content. However, under widely practiced shifting cultivation this horizon has been partly removed or at least has lost its organic matter content. The colour of the B horizon is normally yellowish red to yellowish brown.

The soils have a low natural fertility and are only moderately suited for upland crops (suitability class U-III). Most of the land is covered with open secondary forest or savannah, though dense mixed deciduous and evergreen forests do also occur. Cassava, sweet potatoes, upland rice and other subsistence crops are the main crops grown on these soils.

The soils are associated with Ferralic Cambisols and Dystric Nitosols. Inclusions are Ferric Acrisols and Lithosols.

19. Ferric Acrisols, Petric Phase

The Ferric Acrisols, petric phase, consist of Acrisols having a hard laterite layer or dominant laterite concretions near the surface or at shallow depth. They coincide with the Red Yellow Podzolic Soils with laterite near the surface on the soil map of Thailand and occur also quite extensively on the other side of the Mekong River in Laos. They occur on low plateaux with slightly undulating relief.

The soils are acid and have a very low fertility. The surface layer is sandy to loamy and very gravelly and in many places the soil material is completely eroded and bare consolidated laterite may appear on the surface. Effective soil depth is very shallow (10 to 50 cm. normally) and the soils are covered with open dipterocarp forest or savannah. Some shifting cultivation is carried out in places where the surface soil is deeper. The soils are poorly suited for cultivated crops (suitability class U-IV).

20. Ferric Acrisols Associated with Plinthic Acrisols

This map unit includes the Acrisols having a textural B horizon with many coarse reddish mottles and/or hard iron concretions. They are associated with Plinthic Acrisols having plinthite* in the subsoil. They coincide with the Plinthite Podzols on the soil map of Cambodia and the Grey Podzolic Soils on the soil map of Viet-Nam. The Plinthic Acrisols occur particularly in the areas of East Cambodia and South Viet-Nam that have more than 2,000 mm. rainfall and a short semi-dry season. In all other areas with a pronounced dry season plinthite may occur at large depth and is not of importance for soil classification. In certain areas of this map unit in West Cambodia these soils have dominant iron concretions or hard sheet laterite at shallow depth and are in fact a petric phase of the Ferric Acrisols.

The soils occur on gently undulating to rolling old alluvial terraces or higher terraces with acid rocks. They have a sandy to loamy, greyish brown surface soil, generally with a very low humus content, overlying a weakly developed textural B horizon with a higher clay content. Structure is very weakly developed in these soils. Water holding capacity is low and most soils are extremely dry and hard in the dry season. The soils are acid and have a very low cation exchange capacity and base saturation. They are strongly susceptible to erosion.

Vegetation is generally open dipterocarp forest with shifting cultivation in many areas. Cassava and subsistence crops are the main crops grown. Some soils in the wetter areas are used for rubber. Peanuts are grown successfully in some areas of Viet-Nam, though large lime applications are needed. The soils are moderately suited for upland crops (suitability class U-III).

Inclusions in this map unit are Gleyic and Orthic Acrisols and Ferralic Cambisols.

* Plinthite consists of a soft, sesquioxide rich, highly weathered mixture of clay with quartz, which commonly occurs as red mottles, and which changes irreversibly to a hard laterite layer or irregular iron concretions on repeated wetting and drying.

21. Gleyic Acrisols Associated with Dystric Planosols

This map unit coincides with the Low Humic Gley Soils on the soil maps of Thailand and Viet-Nam and the Cultural and Grey Hydromorphics and Planosols of the soil map of Cambodia.

The Gleyic Acrisols are somewhat poorly to poorly drained soils on low, old alluvial terraces. They are wet for a long period during the rainy season, but dry out deeply in the dry season. They have a loamy surface over a loam to clay textural B horizon. The textural B horizon may be well or weakly developed, while clay increase from A to B horizon is usually rather gradual. The soils have light grey to light greyish brown colours and are strongly mottled throughout. Structure is very weak, particularly in the surface soil. Most of the soils slake very easily and their surface is practically sealed after heavy rainfall. This is partly natural but also brought about by puddling practises for the paddy culture, as the majority of these soils is used for paddy. Many of these soils have a dense ploughpan just below the plough layer in case they have been used for paddy cultivation for a long time. The soils generally have a low organic matter content if not covered by forest. The soil reaction is acid and cation exchange capacity and base saturation are low. The soils therefore have low fertility but due to their relatively poor drainage are moderately suited for paddy (suitability class P-III).

The Dystric Planosols occur in various places, particularly in Cambodia. They are similar soils but characterized by a rather abrupt change in texture between A and B horizon or a very compact impermeable subsurface soil. Also these soils are moderately suited for paddy.

Inclusions are Gleyic Solonetz, Ferric Acrisols and Dystric Gleysols. The latter are acid alluvial soils with a well developed B horizon and a low base saturation. The Gleyic Solonetz have a compact B horizon with very high sodium saturation percentage.

22. Gleyic Acrisols Associated with Ferralic Cambisols and Ferric Acrisols

This map unit coincides with the association of Low Humic Gley Soils and Grey Podzolic Soils or Red Yellow Podzolic soils with laterite on the soil map of Thailand. About half of the map unit consists of Gleyic Acrisols while the other part consists of Ferralic Cambisols and Ferric Acrisols with some inclusions of Dystric Planosols and Dystric Gleysols.

The soils of this map unit all have a low fertility. The low somewhat poorly drained to poorly drained Gleyic Acrisols and Dystric Planosols are used for paddy and the other soils are under open dipterocarp forest or used for shifting cultivation with kenaf or subsistence crops.

23. Dystric Nitosols Associated with Chromic Cambisols

Dystric Nitosols are the dominant soils in the map units designated as Reddish Brown Lateritic Soils and Red Brown Earths on the soil map of Thailand and as Latosols in West Cambodia. Some of the Red Yellow Latosols on Basalt in Thailand are also grouped with the Dystric Nitosols. Also the soils of the Boloven Plateau in Laos are thought to be Dystric Nitosols.

The Dystric Nitosols are very deep, friable, red to dark reddish brown soils on intermediate to basic rocks. They have a clay loam to clay A horizon overlying a clayey textural B horizon. These soils have diffuse horizon boundaries and the B horizon, showing clay coatings on structure aggregates, has increasing clay content to a large depth.

The Dystric Nitosols have a moderately acid soil reaction but base saturation is below 50 percent. Cation exchange capacity is moderate. Organic matter content is variable and highly depending on vegetation cover. Soil fertility is low but the soils have very good physical properties such as friability and high water holding capacity.

The soils are covered with dense forest, or open forest if used for shifting cultivation. Certain parts that are overcultivated have a grass vegetation (mainly *Imperata Cylindrica*). Large areas are used for permanent cultivation and a wide range of crops are grown on these soils of which maize and sorghum are the main ones. The soils are well suited for upland crops (suitability class U-II) though drought in the dry season is an important limitation.

In certain areas the Dystric Nitosols are developed on limestone but are then associated with Chromic Cambisols, which are friable, moderately deep reddish brown soils, which do not have a textural B horizon. Inclusions are Vertisols, Rendzinas and Lithosols.

24. Orthic Ferralsols

The Orthic Ferralsols coincide with most of the Red Yellow Latosols of the soil map of Thailand. They occur on high old alluvial terraces with an undulating to rolling relief.

They are very deep, well drained red to yellowish red soils with a sandy to loamy surface overlying a sandy clay loam oxic B horizon. The upper layers are often slightly degraded and show a weak A2 horizon. The horizon transitions are gradual except for the boundary below the thin, somewhat darker coloured surface layer. The soils have a weakly developed structure, are friable when moist but very hard when dry. The soil reaction is strongly to moderately acid and base saturation is variable. The cation exchange capacity is very low. Organic matter content is generally low but varies with the vegetation cover.

The soils have a low fertility and low water holding capacity. They are moderately suited for upland crops (suitability class U-III). Because of the deep rooting zone fruit trees grow rather well on them. Vegetation is mainly dipterocarp forest with shifting cultivation. The main crop grown on them is kenaf.

Inclusions are Ferralic Cambisols.

25. Rhodic Ferralsols

This map unit coincides with the Reddish Brown Latosols on basalt on the soil map of Viet-Nam, the Latosols in East Cambodia and a small part of the Red Yellow Latosols on the soil map of Thailand.

The soils are deep, friable, dark reddish brown soils on gently undulating to rolling basalt plateaux. They have a clay loam to clay surface overlying a deep clayey oxic B horizon. Horizon boundaries are diffuse. The soils are well drained and porous and have a rather high water holding capacity. The organic matter content is low to moderate related to vegetation cover and slope. They are moderately acid and have a low cation exchange capacity.

Though soil fertility is rather low these soils belong to the best agricultural land of the region due to their very good physical characteristics. A wide range of crops could be grown on them and particularly plantation crops such as rubber and pepper in high rainfall areas and coffee and fruit trees grow very well on them (suitability class U-II). Drought is an important limitation in certain areas and irrigation would be very beneficial for increased agricultural production.

Vegetation is dense mixed forest or open woodland and grass savannah with shifting cultivation. Considerable areas are also under permanent cultivation of plantation crops and field crops.

Inclusions are Orthic Ferralsols, Vertisols and Lithosols.

ANNEX II

Kenaf Baling Plants, Thailand

<u>JBOT</u> <u>No.</u>	<u>Name and Address</u>	<u>No. of Baling</u> <u>Presses</u>
1.	Nam Pong Industry Co., Ltd. Moo 10 Wang Chai, Amphur Nam Pong, Khon Kaen	1
2.	Siam Phan Por Factory Ltd. Part. Moo 4, Ban Nong Wang Muang Phon, Amphur Phon, Khon Kaen	3
3.	Ubon Sin Siri Ltd. Part. 173 Chanyangul Road Kham Yai, Amphur Muang, Ubon Ratchathani	1
4.	Thailand Baling Factory Co., Ltd. Soi Wat Poethong, Tiwanon Road Ban Mai, Amphur Park Kret, Non Buri	1
5.	Poonsin Baling Factory Ltd. Part. 39 Moo 1 Thapra, Amphur Muang, Khon Kaen	2
6.	Poon Pol Co., Ltd. 25/9 Phi boon Songkram Road Dusit, Amphur Dusit, Bangkok	6
7.	Thon Buri Kapok Spinning Ltd. Part. (Jib Hua Seng) 94 Moo 15, Petchkasem Highway Bang Wa, Amphur Phasichalern, Thon Buri	2

Annex II

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
8.	Puech Pol Buriram Co., Ltd. 114/3 Moo 5, Phootaisong Road Esan, Amphur Muang, Buriram	3
9.	Thai Patana Cotton Co., Ltd. 91 Moo 15, Petchkasem Highway Bang Wa, Amphur Phasechlern, Thon Buri	4
10.	Thai Fibers Ltd. Part. 170 Moo 12, Soi Plangnusorn, Suksawat Road Bang Pakok, Amphur Rachburana, Thon Buri	2
11.	Ubon Puech Pol Co., Ltd. 199 Chang Sanit Highway Jaramae, Amphur Muang, Ubon Ratchathani	4
12.	Patana Industrial Co., Ltd. Moo 5, Mitraparb Highway (K.M. 174) Chan Tuk, Amphur Park Chong, Nakorn Ratchasima	1
13.	S.R. International Co., Ltd. 218 Rachruamchalern Bang Pakok, Amphur Rachburana, Thon Buri	2
14.	Phanumaporn Saw Mill Co., Ltd. 4, Soi Phanumaporn, Jom Thong Road Bang Koa, Amphur Bangkuntean, Thon Buri	3
15.	Phinit and Sons Co., Ltd. 527 Soi Plong Arrom, Chan Road Wat Phai Gern, Amphur Janawa, Bangkok	1

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
16.	Saha Mitr Ban Phai Ltd. Part. Moo 4, Chang Sanit Highway (K.M. 15½) Kan Nua, Amphur Ban Phai, Khon Kaen	4
17.	Jung Heng Ltd. Part. 83 Soi Matanusorn, Chalernkrung Road Bang Kolarm, Amphur Janawa, Bangkok	4
	and: 656/2 Chalernkrung Road Bukalo, Amphur Thon Buri, Thon Buri	8
18.	Tai Hua Jan Ltd. Part. 593 Chalern Nakorn Road Bukalo, Amphur Thon Buri, Thon Buri	4
19.	Por Thai Thum Ltd. Part. Ban Sam Liem, Khon Kaen-Udorn Highway Sila, Amphur Muang, Khon Kaen	2
20.	Kasemsuk Baling Factory R.O.P. Moo 22, Stulmark Road (K.M. 2) Tard, Amphur Warinchumrape, Ubon Ratchathani	2
21.	Por Thai Ruang Co., Ltd. Moo 7, Maliwan Road (Khon Kaen-Loei Highway) Muang Kao, Amphur Muang, Khon Kaen	3
22.	P.S. Development Co., Ltd. 127 Moo 19, Rachwat Road Bua Yai, Amphur Bua Yai, Nakorn Ratchasima	3

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<u>JBOT</u> <u>No.</u>	<u>Name and Address</u>	<u>No. of Baling</u> <u>Presses</u>
23.	Thai Wa Co., Ltd. Soi Wat Poethong, Tiwanon Road Ban Mai, Amphur Park Kret, Non Buri	9
24.	Rung Reung Puech Pol Ltd. Part. Moo 4, Chang Sanit Highway (K.M. 16½) Kan Nua, Amphur Ban Phai, Khon Kaen	2
25.	Poon Wattana Co., Ltd. Moo 17, Ban Phai-Muang Pol Highway Ban Phai, Ban Phai, Khon Kaen	3
26.	Saha Por Thai Co., Ltd. 148/1 Maliwan Road (Khon Kaen-Loei Highway) Sila, Amphur Muang, Khon Kaen	5
	and: Bua Yai-Chaiyaphoom Highway Dan Chang, Amphur Bua Yai, Nakorn Ratchasima	1
	and: 232 Nivestrat Road Pon Thong, Amphur Muang, Chaiyaphoom	1
27.	Thavee Sang Thai Baling Factory Ltd. Part. Ban Nong Hin, Udorn Thani-Nong Bua Lamphu Highway (K.M. 3½) Chiang Pin, Amphur Muang, Udorn Thani	2
28.	Intradco Co., Ltd. 1595/2 Soi Kasemsuk, Chalern Krung Road Bang Lamphu Lang, (Bukalo) Amphur Klong San, Thon Buri	3

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
29.	Kaset Ubon Co., Ltd. Ban Hua Kayung, Hua Kayung Railway Station Hua Kayung Samakee Road Ta Lard, Amphur Warinshumrap, Ubon Ratchathani	2
30.	Tang You Kee Baling Factory Ltd. Part. Moo 4, Chang Sanit Highway Kan Nua, Amphur Ban Phai, Khon Kaen	2
31.	Sisaket Baling Factory Ltd. Part Moo 8 Pon Ka, Amphur Muang, Sisaket	2
32.	U-Sahakam Sintuphan Ltd. Part. 169 Pracharach Road Bang Sua, Amphur Dusit, Bangkok	3
33.	Rachburana Pattana Co., Ltd. 105 Moo 5, Soi Wat Seannuwart, Suksawat Road Rachburana, Amphur Rachburana, Thon Buri	1
34.	Wicheansab Ltd. Part. 25/9 Pracharach Road Bang Po, Amphur Dusit, Bangkok	2
35.	Chitchai Ltd. Part. Ban Nong Yai, Moo 6, Khon Kaen-Tha Hin Highway Pralab, Amphur Muang, Khon Kaen	2
36.	Chai Chalern Ltd. Part. 60 Moo 9, Chotiwatana Ta Lard, Amphur Warinshumrap, Ubon Ratchathani	1

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
37.	U-Sahakam Por and Noon Co., Ltd. 130 Moo 1, Udorn Thani-Sakolnakorn Highway Nong Bua, Amphur Muang, Udorn Thani	2
38.	Sui Heng Lee Bua Yai Co., Ltd. 132-134 Moo 19, Nivesrat Road Bua Yai, Amphur Bua Yai, Nakorn Ratchasima	2
39.	Udom Kit Ubon Ltd. Part. 206 Moo 6, Chayangkul Road Kham Yai, Amphur Muang, Ubon Ratchathani	2
	and: JBOT 181, 575 Moo 6 Koon, Amphur Khantrarom, Sisaket	1
40.	Amorn Wattana Nong Khai Factory 289 Moo 1, Panang Cholprathan Road Mee Chai, Amphur Muang, Nong Kai	1
41.	Khoyoo Ha Motors Co., Ltd. 170 Friendship Highway Muang Pol, Amphur Pol, Khon Kaen	4
42.	H.L. Trading Co., Ltd. 4/1 Moo 4, Pathum Thani Highway Bang Kagang, Amphur Muang, Pathum Thani	2
43.	Ruang Chalern Ubon Ltd. Part. 146 Chayangkul Road Kham Yai, Amphur Muang, Ubon Ratchathani	2

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
44.	Ruang Sin Puech Pol Co., Ltd. Moo 4, Chang Sanit Highway Kan Nua, Amphur Ban Phai, Khon Kaen	3
45.	Sin Ubon Co., Ltd. 74 Moo 2, Chayangkul Road Pathum, Amphur Muang, Ubon Ratchathani	3
46.	Out of Business	
47.	Sin Chai Chaiyaphoom Ltd. Part. Moo 2, Chaiyaphoom-Phu Khieo Highway Phonthong, Amphur Muang, Chaiyaphoom	1
48.	Thong Phaisarn Phimai R.O.P. 203 Moo 2, Phibulratjannusorn Road Nai Muang, Amphur Phimai, Nakorn Ratchasima	2
49.	See JBOT No. 145	
50.	Saha Thai Baling Factory Ltd. Part. 106 Moo 1, Chang Sanit Highway Nua Muang, Amphur Muang, Roi-Et	2
51.	Eam Seng Chiang Store 266/2 Suranarai Road Muea Wai, Amphur Muang, Nakorn Ratchasima	1
52.	K.R. Ka Por Nakorn Ratchasima Ltd. Part. 129 Moo 15, Suranarai Road Muea Wai, Amphur Muang, Nakorn Ratchasima	3

<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
53.	Jung Keng Seng Bua Yai Ltd. Part. Moo 17, Nivesrat Road (Bua Yai-Chaiyaphoom Highway) Darn Chang, Amphur Bua Yai, Nakorn Ratchasima	2
54.	Ubon Sum Kung Ltd. Part. 147 Moo 3, Chayangkul Road Kham Yai, Amphur Muang, Ubon Ratchathani	1
55.	Ubon Viwattana Ltd. Part. 315 Thumwithi Road Kham Yai, Amphur Muang, Ubon Ratchathani	2
56.	Tha Tanya Puech Ltd. Part. Ban Na Dee, Moo 14, Nong Bua Lamphu-Udon Thani Highway Chiang Pin, Amphur Muang, Udon Thani	1
57.	Lee Seng Heng Bua Yai Co., Ltd. 56 Ban Nicom, Moo 18, Nivesrat Road Dan Chang, Amphur Bua Yai, Nakorn Ratchasima	2
58.	Chai Mitr Co., Ltd. 1695 Terd Thai Road Talard Pru, Amphur Thon Buri, Thon Buri	2
59.	Lee Tung Seng Ltd. Part. 36 Song Kanong (beside Chuapraya River) Amphur Pra Padang, Samutsongkram	2
60.	Eak Hong Chai Ltd. Part. 20 Munag Mai Road Nai Muang, Amphur Mukdahan, Nakorn Phanom	1

<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
61.	Transferred to Siri Puech Pol Baling Factory Ltd. Part.	
62.	Tang Panich Chaiyaphum Ltd. Part. 69-70 Ban Raj Yai, Moo 1, Nivesrat Road Kut Thum, Amphur Muang, Chaiyaphoom	1
63.	Sin Hu Co., Ltd. 1276-1278 Song Ward Road Somphanwong, Amphur Somphanwong, Bangkok	
64.	Puech Phai Sarn Co., Ltd. 2/1 Moo 2, Non Buri Road, 1 Wat Kae Noak Bang Kasoa, Amphur Muang, Non Buri	3
65.	Out of Business	
66.	Out of Business	
67.	Por Thai Co., Ltd. 87 Moo 19, Nivesrat Road Bua Yai, Amphur Bua Yai, Nakorn Ratchasima	1
68.	Lo Gin Seng Co., Ltd. 240/3-240/4 Praram 4 Klong Toi, Amphur Prakanong, Bangkok	3
69.	Ruammitr Ltd. Part. 722-3 Moo 15, Nivesrat Road Bua Yai, Amphur Bua Yai, Nakorn Ratchasima	1.
70.	Out of Business	

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
71.	Tep Bunjong Ltd. Part. 206 Ban Hua Kajung, Moo 10, Hua Kajung Samakee Road Ta Lard, Amphur Warinchumrap, Ubon Ratchathani	1
72.	Lor Heng Seng Nguan Co., Ltd. 124 Moo 19 Nivesrat Road Bua Yai, Nakorn Ratchasima	3
73.	Chalern Pol Baling Factory Ltd. Part. 178/2 Moo 1, Phattamanon Road Kae Yai, Amphur Muang, Surin	2
74.	Hong Sombat Baling Factory R.O.P. 1506/7 Kukan Road Muang Tai, Amphur Muang, Sisaket	2
75.	A.T.E. Maskati Co., Ltd. 78 Anuwong Road Jakawat, Amphur Somphanwong, Bangkok	
76.	Jin Lee Hong Trading R.O.P. 60 Soi Chalermket 1 Yukul 2 Tepsirin, Amphur Pomprab Sadtrupai, Bangkok	
77.	Thavee Sang Thai U-Sa Ha Kram Co., Ltd. 207 Moo 16, Khon Kaen-Chum Phae Highway Sila, Amphur Muang, Khon Kaen	2
78.	Out of Business	
79.	Out of Business	

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
80.	Out of Business	
81.	Seng Long Chiang Ltd. Part. 120 Moo 1, Chaiphaphoom-See Khew Highway Nong Bua Yai, Amphur Chaturat, Chaiphaphoom	2
82.	Out of Business	
83.	B.K. Import Export Co., Ltd. Moo 2, Soi Ounnute 1, Ounnute Road Tung Bang Jark, Amphur Pra Ka Nong, Bangkok	1
84.	Out of Business	
85.	Out of Business	
86.	Thinakorn Puech Ltd. Part. 135/1-135/3 Moo 4, Chang Sanit Highway Kan Nua, Amphur Ban Phai, Khon Kaen	2
87.	Out of Business	
88.	Udom Ka Puech Ltd. Part. 147 Moo 2, Chanyangkul Road Kham Yai, Amphur Muang, Ubon Ratchathani	1
89.	Siri Thai Por Udorn Thani Ltd. Part. 92 Moo 1, Nitayo Road Nong Bua, Amphur Muang, Udorn Thani	1

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
90.	Sin Kaset Ltd. Part. Moo 6, Taponka, Kuntraluck Road Ponka, Amphur Muang, Sisaket	1
91.	Out of Business	
92.	Far East Fibers Co., Ltd. 218 Chalern Nakorn Road Rachbulrana, Amphur Rachbulana, Thon Buri	1
93.	Ubon Kasikam Ltd. Part. 65 Moo 3, Chayangkul Road Cham Yai, Amphur Muang, Ubon Ratchathani	1
94.	Kitseri Puech Pol Ltd. Part. 97/2 Moo 1, Friendship Road (Khon Kaen- Tha Pra Highway) Tha Pra, Amphur Muang, Khon Kaen	2
95.	Kieat Thai Kasikam Co., Ltd. 131/2-6 Moo 4, Chang Sanit Highway (K.M. 15) Kan Nua, Amphur Ban Phai, Khon Kaen	3
96.	Tai Seng R.O.P. Moo 7, Chaiarya Road Kampang, Amphur Utumpornpisarn, Sisaket	1
97.	Chaiyong Puech Pol Ltd. Part. 34 Moo 1, Chalern Nakorn Road Rachbulrana, Amphur Rachbulrana, Thon Buri	4

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<u>JBOT.</u> <u>No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
98.	Som Khum Puech Pol Ltd. Part. 290 Moo 1 Nong Bua, Amphur Muang, Udorn Thani	1
99.	Sangaun Sin Puech Pol Ltd. Part. 131/17-18 Moo 4, Chang Sanit Highway (K.M. 16) Kan Nua, Amphur Ban Phai, Khon. Kaen	2
100.	Mahasarakam Por Ltd. Part. Moo 2, Chang Sanit Highway Kang Lerng Charn, Amphur Muang, Mahasarakam	2
101.	Chin Num Arhakee Ltd. Part. 1604 Chan Road Tung Wat Don, Amphur Yanawa, Bangkok	1
102.	Chai Viwat Puech Pol Store Moo 18, Nivesrat Road Darn Chang, Amphur Bua Yai, Nakorn Ratchasima	1
103.	Tank You Hong Gua Store 50 Moo 9 Nong Hame, Amphur Utumpornpisai, Sisaket	1
104.	Out of Business	
105.	Eank Panit Ltd. Part. Moo 1 Sumrong Tab, Amphur Sumrong Tab, Surin	1
106.	Rong Por Thavee Puech Pol Ltd. Part. 47 Wareerachded Road Nai Muang, Amphur Yasothorn, Ubon Ratchathani	1

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<u>JBOT</u> <u>No.</u>	<u>Name and Address</u>	<u>No. of Baling</u> <u>Presses</u>
107.	Sahasin Por Baling Factory Ltd. Part. Moo 6, Chaleamrach Road Kool, Amphur Kantrarom, Sisaket	1
108.	Lao Sui Seng Ltd. Part. Moo 5, Nivesrat Road Ban Lard Yai, Amphur Muang, Chaiyaphoom	1
109.	Thai Sawat Nakorn Ratchasima Ltd. Part. 324/2 Moo 2, Suranarai Road Muae Wai, Amphur Muang, Nakorn Ratchasima	3
110.	Yong Somrit Store 154/5 Naresuan Road Mark Chang, Amphur Muang, Udorn Thani	
111.	Sin Udom Surin Ltd. Part. 184/3 Moo 1, Pattananon Road Kae Yai, Amphur Muang, Surin	2
112.	Saha Chalern Rat Ltd. Part. 331 Moo 1, Chaiyaphoom-See Khew Highway Ban Kok, Amphur Jaturat, Chaiyaphoom	2
113.	Hua Heng Chaiyaphoom Ltd. Part. 18-19 Moo 1, Chaiyaphoom-See Khew Highway Ban Kai, Amphur Muang, Chaiyaphoom	2
114.	Thai Aka Chai Ubon Ltd. Part. 237 Chang Sanit Highway Jaramae, Amphur Muang, Ubon Ratchathani	2

<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
115.	Por Laemthong Ltd. Part. Moo 2 Nong Phai, Amphur Chaum Phae, Khon Kaen	2
116.	Ruan Chai Hua Kyunk Ltd. Part. 344 Ban Hua Kyunk, Moo 10, Hua Kyunk Samakee Road Talard, Amphur Warinshumrap, Ubon Ratchathani	1
117.	Rong Sifai Yuen Tanyakit Chaturat Ltd. Part. 3 Moo 2, Chaiyaphoom-See Khew Highway Ban Kok, Amphur Chaturat; Chaiyaphoom	1
118.	Alaska (Panak Por) Ltd. Part. 1043 Terd Thai Road Talard Prue, Amphur Thon Buri, Thon Buri	3
119.	Out of Business	
120.	Ung Heai Guan Store 327 Moo 2, Chayankul Road Kam Yai, Amphur Muang, Ubon Ratchathani	1
121.	Thai Sonserm Port Ltd. Part. Moo 5 Sri Samran, Amphur Kumpawapi, Udorn Thani	1
122.	Out of Business	
123.	Out of Business	

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
124.	Chai Charoen Khasat Co., Ltd. 73 Panichcharoen Road Muang Pol, Amphur Pol, Khon Kaen	1
125.	Khon Kaen Thai Sangoun R.O.P. Ban Makham, Moo 4, Khon Kaen-Tha Hin Highway Pralab, Amphur Muang, Khon Kaen	2
126.	Ponsathorn Ltd. Part. Ban Kham Hai, Moo 9, Maliwan Road (Khon Kaen-Loei Highway) Muang Kao, Amphur Muang, Khon Kaen	1
127.	Pream Dum Rong Ltd. Part. 136/31 Ban Nong Pak Kam, Moo 5, Loei-Chieang Kan Highway Nai Muang, Amphur Muang, Loei	1
128.	Tong Seng Ltd. Part 105-106 Moo 1 Nong Phai Loam, Amphur Sum Rong Tab, Surin	1
129.	Sin Tu Phan Co., Ltd. 114/6 Ban Ma Ka, Moo 5, Putaisong Road Easarn, Amphur Muang, Buriram	2
130.	Out of Business	
131.	Buraphakit Baling Factory Ltd. Part. Moo 7, Amphur Lam Plai Mart-Amphur Nang Rong Highway Lam Plai Mart, Amphur Lam Plai Mart, Buriram	1

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
132.	Rong Noon Bangkok Sang Thai Ltd. Part. 69 Moo 4, Petchkasaem Highway Aumnoi, Amphur Krathumban, Samusakhorn	1
133.	Por Poor Thavee Ltd. Part. 131, Chang Sanit Highway Nai Muang, Amphur Muang, Ubon Ratchathani	2
134.	Kieat Sin Saw Mill Ltd. Part. 130/1 Moo 1, Udorn-Sakorn Nakorn Highway Nong Bua, Amphur Muang, Udorn Thani	1
135.	Oun-Ar-Ree Ltd. Part. 142/1 Moo 4, Udorn-Chiang Pin Highway Chiang Pin, Amphur Muang, Udorn Thani	1
136.	Thai Chai Rat Ltd. Part. 272/1 Moo 5, Nivesrat Road Poanthong, Amphur Muang, Chaiyaphoom	1
137.	Chow Panya Ltd. Part. 479-482 Moo 5 Pandorn, Amphur Kumpawapi, Udorn Thani	2
138.	Ban Phai Laset Sin Co., Ltd. Moo 2, Chang Sanit Highway Nai Muang, Amphur Ban Phai, Khon Kaen	1
139.	Jing You Heng Baling Factory Ltd. Part. Ban Nong Yai, Moo 6, Khon Kaen-Tha Hin Highway Pralab, Amphur Muang, Khon Kaen	1

<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
140.	Khon Kaen Puech Pol Ltd. Part. Moo 7, opp. Khon Kaen University, Maliwan Road (Khon Kaen-Chum Phae Highway) Muang Kao, Amphur Muang, Khon Kaen	2
141.	Srikorn Phum Yuen Yong Phanit Ltd. Part. Nong Kao, Amphur Srikorn Phum, Surin	1
142.	Thai Paka Ltd. Part. 90/8-9 Moo 5, Chang Sanit Highway Nai Muang, Amphur Ban Phai, Khon Kaen	1
143.	Surin Pattana R.O.P. Moo 10, Pattamanon Noak Muang, Amphur Muang, Surin	1
144.	Boon Theam Panich Ltd. Part. Ban Thorn, Moo 4 Chiang Pin, Amphur Muang, Udorn Thani	1
145.	Ung Kee Hong Bua Yai Co., Ltd. 176 Nong Vou Sor Market, Moo 4 Nong Bua-Lam Phu Highway Mark Yar, Amphur Muang, Udorn Thani	1
	and: Moo 10, Bua Yai-Dong Keng Highway Bua Yai, Amphur Bua Yai, Nakorn Ratchasima	1
146.	Por Chalern Puech Pol Utumphorn Baling Factory Ltd. Part. Moo 4, Krom Tang Luang Road Sumrong, Amphur Utumphornpisai, Sisaket	1

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
147.	Por Mee Chai Ltd. Part. Ban Nong Kharm, Moo 14 Chum Phae-Srichomphu Highway Nong Phai, Amphur Chum Phae, Khon Kaen	2
148.	Chai Charoen Baling Factory Ltd. Part. 396 Moo 2, Tad Mai Road Chum Phae, Amphur Chum Phae, Khon Kaen	1
149.	Siri Puech Pol Baling Factory Ltd. Part. Moo 4, Pattamanon Road Chome Pra, Amphur Chome Pra, Surin	2
150.	Tard Phranom Factory Ltd. Part. 149/21 Moo 10, Chayangkul Road Tard Phanom, Amphur Tard Phanom, Nakorn Phanom	1
151.	Yong Huad Phiman R.O.P. Moo 2, Phiboon Rattana Jan Nusorn Road Nai Muang, Amphur Phimai, Nakorn Ratchasima	1
152.	Por Sri Prasert Ltd. Part. Moo 4, Chum Phae-Phu Khieo Highway Chum Phae, Amphur Chum Phae, Khon Kaen	2
153.	Samrit Puech Pol Ltd. Part. Moo 7, Maliwan Road (Khon Kaen-Chum Phae Highway) Muang Kao, Amphur Muang, Khon Kaen	1
154.	Udom Pol Baling Factory Ltd. Part. Ban Nong Kham, Moo 4, Udon Thani- Sakorn Nakorn Highway Nong Bua, Amphur Muang, Udon Thani	2

<u>JBOT</u> <u>No.</u>	<u>Name and Address</u>	<u>No. of Baling</u> <u>Presses</u>
155.	Ruam Charoen Chaiphaphoom Ltd. Part. 12/1 Moo 7, Chaiphaphoom-See Khew Highway Rob Muang, Amphur Muang, Chaiphaphoom	1
156.	Eam Heng Rong Udorn Ltd. Part. Ban Nong Kham, Moo 4, Nittayo Road (Udorn Thani- Sakorn Nakorn Highway) (K.M. 6) Nong Bua, Amphur Muang, Udorn Thani	1
157.	Tieam Prasert Puech Pol Baling Factory Ltd. Part. Moo 2, Chayangkul Road Kham Yai, Amphur Muang, Ubon Ratchathani	1
158.	Sa Ha Por Thai Surin Ltd. Part. Moo 6, Pattamanon Road Kae Yai, Amphur Muang, Surin	2
159.	Nguan Seng Sisaket Baling Factory Ltd. Part Moo 1, Vichit Nakorn Road Poe, Amphur Muang, Sisaket	1
160.	Khangana Suti Ltd. Part. 39/4 Chang Sanit Highway Kuang, Amphur Yasothorn, Ubon Ratchathani	1
161.	Sieang Heng Warin Baling Factory Ltd. Part. 158/1 Satolmark Road Warin, Amphur Warinshumrap, Ubon Ratchathani	1
162.	Ran Rong Ude Por and Noon Park Nam Phai Fiber Store 241 Moo 10, Phaholyotin Highway Nakorn Savan Tok, Amphur Muang, Nakorn Savan	2

<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
163.	Prasarnmitr Baling Factory Ltd. Part. Moo 3, Teenanond Road Nua, Amphur Muang, Kalasin	1
164.	Phattana Kitr Baling Factory Ltd. Part. Ban Kae Yai, Moo 1, Pattamanon Road Kae Yai, Amphur Muang, Surin	1
165.	Mor Din Dang Baling Factory Ltd. Part. Moo 14, Friendship Highway Nai Muang, Amphur Muang, Khon Kaen	1
166.	Ubon Kim Monk Ltd. Part. 178 Moo 4, Chayangkul Road Kham Yai, Amphur Muang, Ubon Ratchathani	1
167.	Ubon Chalern Baling Factory Ltd. Part. 201 Moo 3, Chayangkul Road Phatum, Amphur Muang, Ubon Ratchathani	1
168.	Por Sin Chai Ltd. Part. Moo 7, Maliwan Road Muang Kao, Amphur Muang, Khon Kaen	1
169.	Boon Thavee Puech Pol Ltd. Part. 82/3 Moo 5, Chang Sanit Highway Nai Muang, Amphur Ban Phai, Khon Kaen	1
170.	Sri Chalern Baling Factory Ltd. Part. Moo 5, Kantralack Road Phoneka, Amphur Muang, Sisaket	1

<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
171.	Arkanay Cotton Co., Ltd. Ban Nong Pak Kham, Moo 5, Loei-Chian Kan Highway Muang, Amphur Muang, Loei	1
172.	Sisaket Dumrong Kittr Ltd. Part. Moo 5, Kantrakack Road Nong Krock, Amphur Muang, Sisaket	1
173.	Sathit Wattana Ltd. Part. Chaiyaphoom-Phu Khieo Highway Phonethong, Amphur Muang, Chaiyaphoom	1
174.	Amnuan Puech Pol Chatulack Ltd. Part. 89-90 Moo 1, Chaiyaphoom-See Khew Highway Ban Kok, Amphur Chaturat, Chaiyaphoom	1
175.	Siri Sakorn Baling Factory Ltd. Part. Ban Wang Sapung, Moo 6, Khon Kaen-Loei Highway Wang Sapung, Amphur Wang Sapung, Loei	2
176.	Kaset Thai Ban Phai Ltd. Part. 42/1 Moo 4, Ban Phai-Borabu Highway Kan Nua, Ban Phai, Khon Kaen	1
177.	Chaturat Saguan Thai Ltd. Part. 28 Moo 1, Chaiyaphoom-See Khew Highway Nong Bua Yai, Amphur Chaturat, Chaiyaphoom	1
178.	Ban Phai Por Thai Ltd. Part. Moo 21, Chang Sanit Highway Ban Phai, Amphur Ban Phai, Khon Kaen	2

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
179.	Bang Pakok Kan Fai Industrial Co., Ltd. 199 Moo 2, Soi Arnamai, Suksawat Road Bang Pakok, Amphur Rachbulana, Thon Buri	1
180.	Chaiyapoonpol Baling Factory Ltd. Part. Moo 1, Friendship Highway Tha Pra, Amphur Muang, Khon Kaen	1
181.	See JBOT No. 39	
182.	Soothorn Kaset Ltd. Part. 35/2 Moo 6, Pattamanon Road Rob Muang, Amphur Muang, Roi-Et	2
183.	Thai Yone Baling Factory Ltd. Part. Ban Nong Muaek, Moo 5, Sisaket-Kantralack Highway Nong Krock, Amphur Muang, Sisaket	1
184.	Chai Siri Buriram Baling Factory Ltd. Part. 105 Thanee Road Nai Muang, Amphur Muang, Buriram	1
185.	Korach Sin Chalern Ltd. Part. 3858/7-3858/9 Suranarai Road Nai Muang, Amphur Muang, Buriram	1
186.	Chum Phae Puech Pol Ltd. Part. Ban Nong Phai, Moo 2, Ban Nong Phai Highway Nong Phai, Amphur Chum Phae, Khon Kaen	1
187.	Thai Poon Pol Buriram Ltd. Part. Buriram-Prakon Chai Highway Easarn, Amphur Muang, Buriram	1

<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
188.	Tiea Sui Sae Store (Rong Por Tiea Sui Sae) Suranarai Road Muaen Wai, Amphur Muang, Nakorn Ratchasima	2
189.	Ngee Hong Long Bua Yai Co., Ltd. Moo 15, Bua Yai-Dong Kheng Highway Bua Yai, Amphur Bua Yai, Nakorn Ratchasima	1
190.	Thai Easarn Surin Baling Factory Ltd. Part. 32/1 Moo 13, Surin-Chonjom Highway Chneang, Amphur Muang, Surin	1
191.	Buriram Ruammitr Ltd. Part. Moo 9, Buriram-Nang Rong Highway Easarn, Amphur Muang, Buriram	1
192.	Khun Sin Ltd. Part. Ban Hua Na, Moo 2, Friendship Highway (Between K.M. 499 and 500) Nong Ma Khua, Amphur Pol, Khon Kaen	1
193.	Ruang Udom Lam Praimart Ltd. Part. Ban Lam Praimart, Moo 1 Lam Praimart, Amphur Lam Praimart, Buriram	1
194.	Sri Karaphum R.O.P. Moo 2 Ragang, Amphur Sri Karaphum, Surin	1
195.	Jing Heng Store 74/3-74/5 Moo 5, Chang Sanit Highway Nai Muang, Amphur Ban Phai, Khon Kaen	1

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<u>JBOT No.</u>	<u>Name and Address</u>	<u>No. of Baling Presses</u>
196.	Charoen Pol Ltd. Part. Ban Nong Samor, Moo 11, Friendship Highway Kao Ngue, Amphur Pol, Khon Kaen	1
197.	Parit Pol Puech Rai Ltd. Part. 211 Moo 3 Nai Muang, Amphur Phimai, Nakorn Ratchasima	1
198.	Kim Heng Chieang Ratchasima Ltd. Part. Moo 2, Suranarai Road Muaen Wai, Amphur Muang, Nakorn Ratchasima	1
199.	Khon Kaen Suthipol Ltd. Part. 85/5-7 Moo 5, Chang Sanit Highway Nai Muang, Amphur Ban Phai, Khon Kaen	1
200.	Ratchasima Ka Por Ltd. Part. 45/1 Mitraparp Highway Nong Ya Bok, Amphur Muang, Nakorn Ratchasima	1
201.	Por Krungtep Co., Ltd. 3, Near Viriyachai Bridge, Klong Downkanong Suksawat Road Bukalo, Amphur Thon Buri, Thon Buri	2
202.	Pattana Panitr Baling Factory Ltd. Part. 109 Moo 1, Arphairach Road Putaisong, Amphur Putaisong, Buriram	1
203.	Thai Buriram Baling Factory Ltd. Part. Moo 4 Easarn, Amphur Muang, Buriram	1

<u>JBOT</u> <u>No.</u>	<u>Name and Address</u>	<u>No. of Baling</u> <u>Presses</u>
204.	Kim Seng Nguan Baling Factory Ltd. Part. 157 Moo 9 Nong Hang, Amphur Utumpornpisai, Sisaket	1
205.	Sin Chaiyaphoom Baling Factory Ltd. Part. 47 Moo 2, Chaiyaphoom-Phu Khieo Highway Amphur Muang, Chaiyaphoom	1
206.	Ban Phai Kaset Pattana Ltd. Part. 181 Moo 22, Chang Sanit Highway Ban Phai, Amphur Ban Phai, Khon Kaen	
207.	Kittavee Baling Factory Ltd. Part. Moo 6, Selaphum-Phong Thong Highway Na-Muang, Amphur Selaphum, Roi-Et	
208.	Dacha Development Co., Ltd. 127/3 Moo 19, Niwatratan Road Bua Yai, Nakorn Ratchasima	
209.	Phon Than Baling Factory Amphur Muang, Khon Kaen	
210.	Sahachai Baling Factory Moo 20, Amphur Chum Phae, Khon Kaen	
211.	Sahamitr Ltd. Part. 135/16 Moo 4, Chang Sanit Highway Ban Phai-Kan Nua Highway Amphur Ban Phai, Khon Kaen	

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<u>JBOT</u> <u>No.</u>	<u>Name and Address</u>	<u>No. of Baling</u> <u>Presses</u>
212.	Ruang Sin Thai Puech Pol Co., Ltd. 138/4 Moo 4, Chang Sanit Highway Amphur Ban Phai, Khon Kaen	
213.	Yong Sumut Ltd. Part. Moo 8, Chiang Phin Chiang Phin, Amphur Muang, Udorn Thani	
214.	Chit Chai Baling Factory 88/4 Moo 6, Khon-Yang Thalath Highway Amphur Muang, Khon Kaen	
215.	Thai Sanguan Baling Factory 38/4 Moo 4, Khon Kaen-Yang Thalath Highway Amphur Muang, Khon Kaen	
216.	Lam Thong Baling Factory Ltd. Part. Moo 2, Maliwan-Chum Phae Highway Khon Kaen	
217.	Tana Chai Roi-Et Baling Factory Ltd. Part. 106 Chang Sanit Highway Amphur Muang, Roi-Et	
218.	Takal Chai Baling Factory Ltd. Part. 210 Moo 5, Pan Don Kumpawapi, Udorn Thani	
219.	Amorn Watana Factory 249 Chonpatan Mee Chai Amphur Muang, Nong Khai	

ANNEX III

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ANNEX IV

List of Persons Interviewed

Bangkok

Applied Scientific Research Corporation of Thailand
Bangkhen

Dr. Kasem Balajiva, Research Director
Technological Research Institute
Dr. Narong Chomchalow, Research Director
Agricultural Products Research Institute

Board of Investment

Mr. Pairote Gesmankit, Chief
Investment Services Division
Mr. Pramote Permpanich, Chief
Project Development Division

Committee for Coordination of Investigations
of the Lower Mekong Basin

Mr. W.J. van der Oord, Executive Agent
Mr. Henry Beyda, Chief
Mekong Administrative Section, ESCAP
Dr. Prachoom Chomchai, Director
Economic and Social Studies Division
Mr. Thaipuck Thammongkol
Hydrologist

Ministry of Commerce

Mr. Phot Inganinanda, Director
Trade Policy Division
Department of Business Economics

Ministry of Industry

Mr. Saman Thangtongtawi, Engineer
Factory Environmental Control Division
Department of Industrial Works
Mrs. Sumitra
Statistics Section
Department of Mineral Resources
Mr. Vichien Sakornmonkol, Director
Research Division
Department of Science

Ministry of Industry (Cont'd)

Mr. Vira Susangkorakan, Deputy Director-General
Department of Industrial Works
Mr. Visith Noiphan, Chief
Factory Environmental Control Division
Department of Industrial Works
Mr. Wis Wannaying, Engineer
Department of Industrial Promotion

Ministry of the Interior

Mr. Vichit Piyarom, Deputy Director
Division of Land Settlements
Public Welfare Department

National Economic and Social Development Board

Mr. Krit Sombatsiri, Deputy Secretary-General

Electricity Generating Authority of Thailand

Mr. Subhin Panyamag

Provincial Electricity Authority of Thailand

Mr. Sookchai Lophongse

Royal Irrigation Department

Mr. Charin Atthayodhin

Food and Agriculture Organization of the United Nations (FAO)

Mr. Joseph Turbang
Regional Forestry Officer
FAO Regional Office for Asia & Far East

United Nations Industrial Development Organization (UNIDO)

Mr. Kurt W.R. Aselmann
Senior Industrial Advisor
Mr. Bo Jerlstroem
Dr. H.G.R. Reddy
Regional Industrial Advisor

American Embassy

Regional Economic Development Office
Dr. Thomas C. Irvin, Director
Dr. Kenneth M. Rabin, Ex-Director
Mr. Louis A. Cohen, Deputy Director
Mr. James Hanks, Mekong Project Officer
Mr. Russell Parr

John Deere International Ltd.

Mr. Gary McLeuan

Christiani & Nielsen (Thailand) Ltd.

Mr. Hans Steensen, Managing Director

Mr. Vichien Kidakarn, Chief Engineer

Mitsui Trading Company

Mr. Shiotani

Mr. Viroj

Price & Pierce (Far East) Ltd.

Mr. D.M. Balzar

The Siam Kraft Paper Co., Ltd.

Mr. Robert D. Stratton

Thai Asahi Caustic Soda Co., Ltd.

Mr. Dusit Salakshana, Executive Director

Thai Pulp Co., Ltd.

Mr. Wang Theravuthi, General Manager

Northeast Thailand

Mr. Laph Tanthasri, Chief

Northeast Irrigation Region

Nakorn Ratchasima

Mr. Sanan Siripat, Chief

Nam Takong Dam

Royal Irrigation Department

Nakorn Ratchasima

Ubolratana Dam, Khon Kaen

Mr. Narong Buavirat, Engineer

Mr. Samrerng Kerdkosum

Mr. Detchard Vongkomolshet

Deputy Governor

Ubon Ratchthani

U.S.A.

Mr. Somphong Wanapha, Chief Representative
Board of Investment (Thailand)
New York, New York

Northern Regional Research Laboratory
Peoria, Illinois

Mr. Marvin O. Bagby, Research Leader

Mr. Gerald F. Touzinsky, Research Chemist